Physico-chemical Constituents & Engineering-properties of Food Crops

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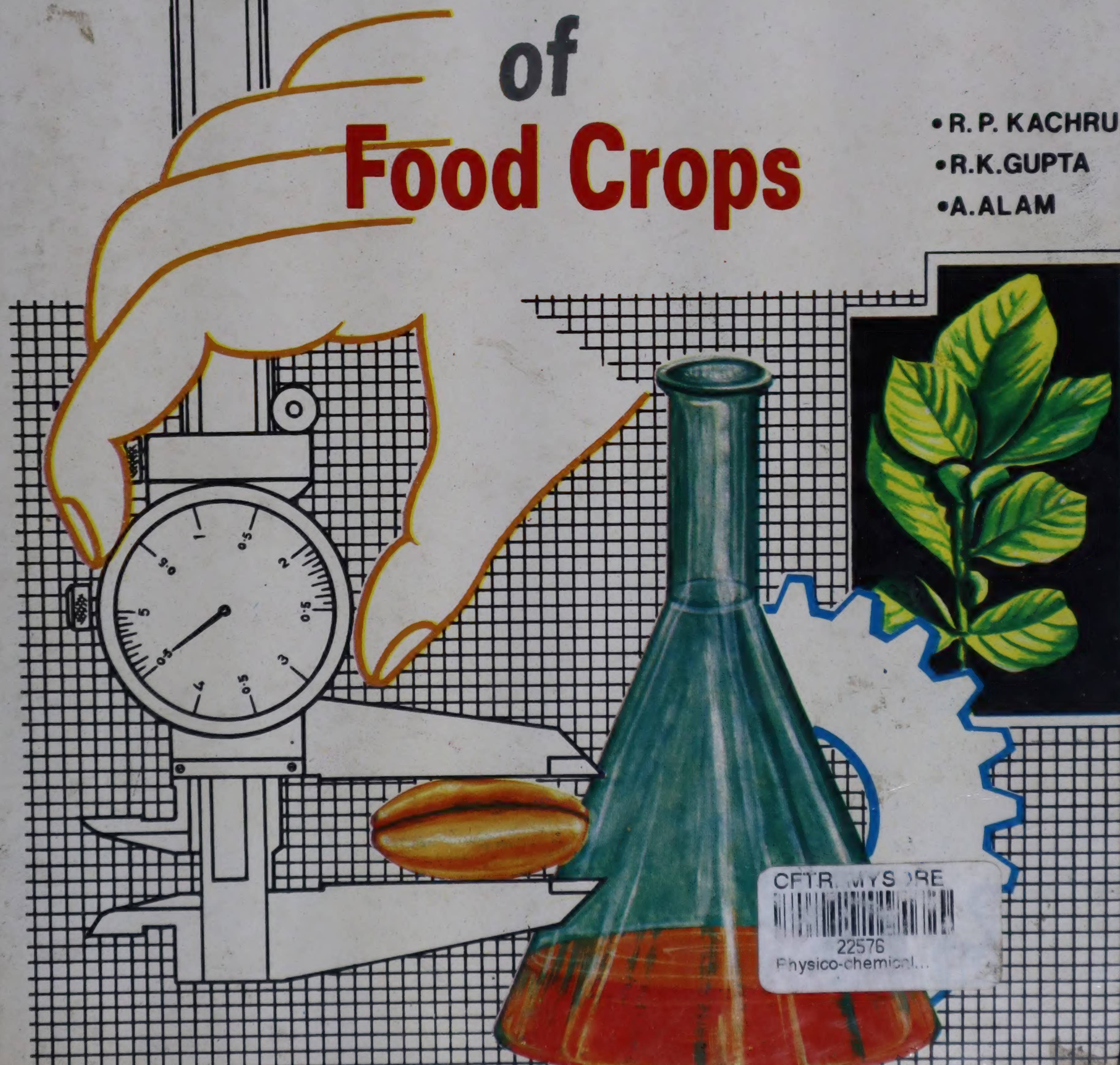

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1. food byproducts
2. gravimetric properties
3. aerodynamic properties
4. rheological properties
5. thermal properties.
6. hygroscopic protesties.

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Physico-Chemical Constituents and Engineering Properties of Food Crops

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SCIENTIFIC PUBLISHERS, JODHPUR

Published by
SCIENTIFIC PUBLISHERS
5A, New Pali Road,
P.O. Box. 91
Jodhpur–342 001, INDIA

First Published 1994

ISBN : 81-7233-083-9

Typeset by
Akshya Kumar Chakravartty

Printed in India

FOREWORD

This publication is an important contribution in the discipline of Post Harvest Engineering and Technology. Knowledge and reliable data about dimensions and behavioural properties of agricultural crops and animal products are needed for designers of equipments and processes, operators of processing plants and researchers. This book fills a felt need. It is to be noted that all the information given is based on varieties of crops grown and used in India, and therefore, relevant for ready use.

The book covers a wide area as ably explained in the Introduction. However, it does not contain information on electro-magnetic properties as probably no research work is done and no data are available. There is no data on surface areas of grains and very limited on fruits etc. Generally speaking, 14 per cent moisture content (on dry basis) of biological materials is used for comparison.

The publication is very rich in information on the subject matter, is very timely, well prepared and organized and is a mile stone. The authors deserve lot of credit for bringing out this publication on Physico-Chemical Constituents and Engineering Properties of Food Crops.

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PREFACE

Food processing activities must increase to maintain a continuous and quality food supply and to increase economic returns through value-addition of raw agricultural produce. From the production units on the farm to the consumer, food materials are subjected to various physical and chemical treatments, involving mechanical, thermal and biological techniques and devices. The systematic information on physical constituents and engineering properties of food crops thus, plays an important role in designing the machines, processes and handling operations which may lead to optimization of various parameters, efficiency of operation and quality of the end product. Besides, scientifically based improvements in the existing technology, processes, systems and equipment require in-depth study of engineering properties of food materials. The information on chemical constituents of food materials will be helpful in assessing the nutritive value of existing diets and in correcting inadequacies therein through a judicious choice of available food stuffs.

Considerable research data on various engineering properties, physical and chemical constituents of food crops have been generated and published in scientific journals, reports etc. However, the information is not readily availble to the users since no compilation of data has been done at one place. Besides, till recently, the properties of various food crops were mainly based on the work carried out in other countries. This book is an attempt of its own kind to place significant research data based on Indian work on physico-chemical constituents and engineering properties of food crops under one cover.

The publication has been divided in eight chapters covering topics on physico-chemical constituents of food crops, definitions and methods for determination of physical, mechanical, thermal and biological properties of food materials. At the end of each chapter, research data on engineering properties collected from various sources have been given in the form of tables. The data presented in the book are based mostly on Indian work and more particularly, the work carried out at various Centres of All India Coordinated Research Project on Post Harvest Technology (ICAR). The standard curves for various properties and instrumentation required for their determination are also given in the book. Glossary of food products with botonical and hindi names provided at the end may make it more convenient to the users.

The contents of the book are so grouped to facilitate its usage as text or reference material for students and teachers in technical universities as well as researchers in any branch of science and technology and engineers concerned with physical behaviour of food materials.

BHOPAL

Dr. NSL SRIVASTAVA
DIRECTOR, CIAE

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ACKNOWLEDGEMENT

We are grateful to Dr. NSL Srivastava, Director, Central Institute of Agricultural Engineering, Bhopal for his encouragement in bringing out this publication. We are also thankful to him for writing "Preface" for this book. Authors are greatly indebted to Prof. AC Pandya for going through the manuscript and writing " Foreword " for it.

We sincerely appreciate the painstaking work of Mr. JT Sheriff, Scientist, CTCRI, Trivandrum, in the perparation of the manuscript. The help rendered by Mr.V.Natekar in the preparation of ink drawings Mr. H. S. Sriwas in the cover design and Mr. ZV John for typing the manuscript is greatly appreciated.

This publication would not have been possible without the co-operation of scientists/engineers, who were approached for giving valuable informations. It would be impossible to name and acknowledge individuals for making use of their published papers, books, bulletins, reports, illustrative material etc. in the preparation of this book. However, an attempt has been made to indicate the sources of all materials used throughout the book. The bibliographical references to these sources are also given at the end of this publication. Special acknowledgement is made for using the data on chemical composition of food crops, taken from the book entitled "Nutritive Value of Indian Foods" (edited by Gopalan, C. et al., 1982).

This book, being the first publication of its own kind in placing significant research data based on Indian work on physico- chemical constituents and engineering properties of food crops under one cover, it may be, that there exist some gaps in the information collected/reported. The authors would thus, appreciate for any feed back from the readers by providing additional data and information for the improvement of the future edition of the book.

This book gives fair representation of important engineering properties and data on physico-chemical constituents of food crops at one place. Thus, it may prove to be a text or reference material for students and teachers in technical universities, engineering colleges, polytechnics as well as for researchers and engineers involved directly or indirectly with the physical behaviour of food materials.

BHOPAL

Dr. R.P. Kachru
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INTRODUCTION

The physical constituents and engineering properties of food crops are important for the design of machines, processes and analysis of the behaviour of the product in their handling and processing. The information on the major chemical constituents, viz: carbohydrate, protein and fat content of food crops, would be helpful in making a balance diet. While processing, the material used undergoes to different degrees of heat and moisture treatment which may alter the composition of these constituents and sometimes, may lead to lower nutritive value.

The raw material rich in protein and carbohydrate should not be exposed to higher temperatures while preparing food because carbohydrates and protein form carbonyl complexes and depending on their degree of polymerization, the food becomes dark in colour and bitter in taste besides, the nutritive value decreases. Oil bearing materials, depending upon temperature, moisture, availability of oxygen and the lipid profile go through varying degree of oxidative changes, rancidity and refining losses. Though the vegetables do not form the bulk of diet, they are major source of valuable vitamins and essential minerals, each having then typical chemical composition. In case of high oxlate containing vegetables like spinach, care should be taken to combine these oxlate rich materials with lower level of calcium containing food systems which would facilitate formation of calcium oxlate precipitate preventing oxlates being assimilated and becoming cause of stone formation. On the basis of the compositions, dieticians can formulate hazard free diet.

Food rich in protein and low in simple carbohydrates are needed for diabetics. All these call for the relevant information on chemical compositions of food crops which form constituents of the dishes that we eat. Such information is also useful in the production of livestock feeds. Deep understanding of chemical and nutritional compositions helps development of high value products using relatively low cost raw materials.

Measurement of engineering properties of food grains are the parameters of great importance for analysis of behaviour of grains during handling, drying, processing, storage and designing the machinery.

Post harvest operations of food materials involving handling and processing by mechanical and/or thermal techniques and devices call for full understanding of size, shape, surface area, volume, particle and bulk density and porosity, static and dynamic co-efficients of friction, specific heat, thermal conductivity, thermal diffusivity and latent heat of various food materials. Conservation of food through drying, dehydration and scientific storage calls for full understanding of hygroscopic nature of food materials. Aerodynamic properties such as, terminal velocity, drag co-efficient are needed for pneumatic conveying and separation.

The physical characteristics of seed or grain are important and useful for the design of the processing equipments. The physical characteristics are also important in the design of seed drills and storage structures. Besides, the information regarding physical properties of grain and seed could be utilized for their classification into different grades as fine, medium and coarse for commercial use.

INTRODUCTION

When physical properties of grains, seeds, fruits and vegetables are studied by considering either bulk or individual units of the material, it is important to have an accurate estimate of shape, size, surface area and other physical characteristics which may be considered as engineering parameters for that product.

Shape and size are important parameters which govern design of winnowers, cleaners and graders, for separating the grains from foreign materials and in the development of the grading machinery. In conveying of solid materials by air or water, estimate of frontal area and related diameters are needed for determination of terminal velocity, drag co-efficient and Reynold's number. Size and shape are also important factors in the analysis of problems of stress distribution under load, heat mass transfer, pneumatic and hydraulic handling and separation and electrostatic separation of seeds and grains.

Gravimetric properties such as, specific gravity, bulk density are important in design and analysis of separation, handling, drying, processing, storage and transport equipment and systems. Specific gravity is a widely used criteria for separation of food materials. Bulk density decides the capacity of storage structures, hoppers and in determining resulting loads which must be taken in to consideration in the design of their components. The knowledge of density and specific gravity of grain is also needed in solutions of transport problems, in determining Reynold's number in pneumatic and hydraulic handling of the material and in separating the grain from undersize.

Porosity of the solid mass governs the resistance to air flow in a dryer and dictates the bed thickness which can be dried safely and the type of blower needed. The per cent voids of a consolidated and unconsolidated mass of porous materials is often required in air flow and heat flow studies as well as in other applications.

Static and sliding friction co-efficients of grains and other food materials on metal, wood and other surfaces are needed by the design engineers for rational design, predicting motion in handling, determining pressure of grain against bin walls and silos. Co-efficient of internal friction is important in studying consolidation and compressibility of the material and determining methods of compressing and packaging. The handling and flow of the material requires a better understanding of the frictional properties, angle of repose etc. This, in turn, helps in the design of belt conveyors, screw conveyors etc.

Aerodynamic properties such as terminal velocity and drag co- efficient are needed for air conveying and separation of materials. In air conveying or pneumatic separation, an air velocity greater than terminal velocity lifts the particles. Rheological properties such as compressive strength, impact and shear resistance, hardness, co-efficient of restitution and deformation load are important and in some cases, necessary engineering data in studying size reduction of food grains as well as resistance to mechanical injury to the seed under mechanical threshing and handling. Similarly, the crushing load of a material plays an important role in determining milling characteristics in combination with the moisture content.

Many of the food grains and the products are subjected to various types of thermal processing before they are placed at the disposal of consumers. It may involve heating, cooking, drying and freezing. These call for information about the specific heat, thermal conductivity, thermal diffusivity and latent heat associated with the various food materials. Grain drying and storage are of the prime importance to the agricultural industry. Many of the problems encountered in drying and storing may be analysed by using heat transfer principles. For example, temperature changes may be calculated by use of the basic heat transfer equations. The use of these equations, necessitates, the knowledge of the thermal properties of the grains. The specific heat,

thermal conductivity and thermal diffusivity must be known before the equations of heat flow can be used. Consideration of heat transfer is not limited to problems of grain drying and storing but may be used for analysis of other processes such as aeration and refrigeration. Measurement of the thermal conductivity of agricultural products of various types such as granular materials and powdered materials are important for designing and controlling operations, where such materials are subjected to heating, cooling, drying or freezing.

The moisture content of food materials exerts a profound influence on their physical and biological properties. It is of major concern in handling, processing and storage of food materials. Hygroscopicity of food materials is usually measured by determining equilibrium moisture content, it maintains, at a given temperature and relative humidity.

CHAPTER-1

PHYSICO-CHEMICAL CONSTITUENTS AND PROPERTIES OF FOOD CROPS AND THEIR BY-PRODUCTS

The physical parameters, viz; plant height, number of branches, clusters, pods and seeds per plant are used to predict the yield of a particular food crop. The information on the plant parameters is also important to assess the need of agronomical inputs like cultural practices, application of fertilizer and weed control to overcome the deficiencies at the initial stage of the crop growth. Whereas, measurement of physical constituents of the food crops, viz; grain to crop ratio, grain to straw ratio and grain fractions are important for the design of harvesting/threshing machines, processes and analysis of the behaviour of the product in their handling and processing. It also quantifies the various constituents for their better utilization.

For the measurement of physical parameters, plants are to be counted/measured during field experiments. The lot size may vary according to the situation such as, crop plot size and purpose for which observations are being taken. However, a minimum of 100 plants, pods and/or grains should be taken for the determination of the said parameters. Physical constituents of cereals, pulses, oilseeds, fruits, spices and other crops are given in Tables 1.1 to 1.4.

The information on the major chemical/nutritional constituents, viz; carbohydrate, protein and fat content of food crops would help in the development of high value and new products using relatively low cost raw materials and for making balance diet. For the determination of major chemical constituents of food crops, standard methods/procedures, described in Association of Official Analytical Chemists (AOAC) may be followed. Chemical constituents of cereals, pulses, oilseeds and fruits, vegetables, spices and other crops are given in Tables 1.5 to 1.8.

The knowledge on physico-chemical properties of oils, viz; specific gravity, refractive index, apparent density, iodine value, FFA etc. are useful to monitor the quality of oils during processing, handling and storage. These properties may be determined by using methods given in American Oil Chemists Society (AOCS). Physico-chemical properties of oils are given in Table 1.9. Additional information on chemical composition of food crops and their by-products are given in Table 1.10.

Table 1.1: Physical constituents of cereals

Crop/Variety	Constituents	Reference
Finger millet		
Local	Grain to straw ratio =1 : 4	57
Maize (corn)		
Local	Cob length: 200 mm Cob diameter: 46 mm Cob girth: 119.9-146.0 mm No. of grains/cob: 423 Dry matter: 89.5% Grain to stalk ratio =1:3 Grain to cob ratio = 1:15 **Grain fraction** Endosperm: 79-83% Germ: 10-12%	59,97,131
G-5	Straw moisture content (m.c.) =17.4% (db) Grain m.c. =12.6% (db) Straw grain ratio = 1:6.7	
Paddy		
Local	Grain to straw ratio = 1 : 2 **Grain fraction** Hull: 18-22% Germ: 1-2% Endosperm: 70-72% Bran: 4-6%	98, 133, 136,164,174
Pusa-221	Straw m.c.: 13.9% (db) Grain m.c.: 16.9% (db) Straw grain ratio = 1:0.67	
IR-36	Grain to crop ratio = 1:2.2—1:1.9 Grain m.c. = 8.7-14.9%(db)	

	Days to 50% flowering	Plant height, mm	Panicle length, mm	Grains/ panicle	Filled grains/ panicle	Grain yield, g/plant	Shoot dry weight, g/plant	Total tillers/ plant	Fertile tillers/ plant
	1.	2.	3.	4.	5.	6.	7.	8.	9.
Bala	58	680	168	75.3	–	–	–	–	–
Bashat	54	930	198	60.6	–	–	–	–	–
Bile kagga	–	–	–	124.3	85.1	12.2	36.2	14.6	11.5
Char nock	–	–	–	104.3	86.8	13.4	18.0	13.9	11.5
Chinee 988	71	1020	223	82.6	–	–	–	–	–
CSR–1	–	–	–	128.6	97.4	10.2	20.5	11.4	9.3
CSR–1 Mutant	–	–	–	131.4	94.3	11.7	16.4	11.9	9.3
CSR–2	–	–	–	135.8	99.1	9.9	23.2	11.8	9.4
CSR–3	–	–	–	135.4	99.5	9.5	18.9	10.9	8.4
Govind	76	760	192	82.4	–	–	–	–	–
IRAT-8	–		–	161.7	124.4	10.9	11.4	7.1	5.7
IR–36	87	710	202	81.2	–	–	–	–	–
IR–58	59	950	224	110.4	–	–	–	–	–
IR–4227–109–1–3–3	–	–	–	116.4	96.2	17.6	19.3	11.4	9.3
IR–4462–22A2–10	–	–	–	96.3	77.1	11.9	19.4	9.2	7.9
IR–4630–22–2–5–1–2	–	–	–	116.7	92.9	13.1	20.0	10.4	8.4

Table Contd....

	1.	2.	3.	4.	5.	6.	7.	8.	9.
IR–5178–1–1–4	70	1050	197	93.9	–	–	–	–	–
IR–8192–200–3–3–1–1	–	–	–	112.10	81.0	13.2	21.1	12.4	10.1
Kare kagga	–	–	–	88.5	73.4	10.2	14.7	6.7	5.5
M–224	–	–	–	106.7	97.1	15.6	26.9	18.9	14.4
MCM–1	–	–	–	100.5	93.4	21.2	29.0	13.5	12.0
Narendra–1	77	790	194	89.7	–	–	–	–	–
N–22	66	820	178	88.2	–	–	–	–	–
Oorgondon	–	–	–	146.6	124.6	18.7	23.9	13.8	10.9
PAU–21–88–5	–	–	–	111.9	93.7	16.4	21.2	12.1	9.6
Toduken	–	–	–	129.5	89.5	13.2	18.1	18.1	14.7
UPR–Pusa–33	75	700	194	89.5	–	–	–	–	–
UPR–79–9	73	760	206	72.2	–	–	–	–	–
UPR–79–151	67	690	193	73.8	–	–	–	–	–
UPR–79–168	56	900	167	71.3	–	–	–	–	–
UPR–79–169	57	940	180	87.1	–	–	–	–	–
UPR–82–31	73	800	179	101.2	–	–	–	–	–
UPR–83–169	64	970	170	75.1	–	–	–	–	–
UPR–103–D7–1	78	770	218	103.2	–	–	–	–	–
VL–16	80	1160	272	102.3	–	–	–	–	–
VL–206	78	1290	225	116.0	–	–	–	–	–

	Moisture content, % (db)	Husk, % (by wt.)	Bran, % (by wt.)
Bad Shahbhog	13.7	21.0	6.3
Bora	14.0	23.2	9.4
Chilarai	13.8	20.0	7.5
Gajepsali	14.0	19.2	7.8
IET-6666	14.1	20.1	4.2
IET-8021	14.1	20.2	5.7
Jahinga	14.2	21.2	5.2
Kalajaha	13.9	20.0	6.8
Mahsuri	14.1	21.2	6.5
Manoharsali	13.8	19.2	7.2
Masuri	14.0	20.9	6.2
Nekera	14.1	21.3	6.4
Pakhi Bara	13.8	24.2	4.3
Pankaj	14.4	20.7	5.2
Ranga Sali	14.3	22.2	7.0
Rochi	14.2	20.3	8.9
Rongile	14.2	22.4	5.2
Sakowa	14.3	20.8	8.9
Salpona	13.8	22.3	5.4
Telkuchi	13.8	20.9	5.3

Table Contd.....

Crop/Variety	Constituents	Reference
Pearl millet		
Local	Plant height : 1,300—1,450 mm; Tillers/plant : 6—10; Earhead length = 220–260 mm; Grain to straw ratio = 1 : 4	105

	Fingers/ earhead	Finger length, mm	Finger width, mm	Spikelets per finger	Grains per finger	Grain appearance	
Ragi							57
Indaf-8	5—10	64—118	12—15	52—120	4	Reddish brown	
HR—911	6—8	65—114	12—18	53—112	5	Brown	
Local	2—7	40—95	10—14	43—67	3	Dark brown	

Crop/Variety	Constituents		Reference
Rice (brown)			
General	Pericarp	: 1-2%	69,122
	Aleurone, nucellus and seed coat	: 4-6%	
	Embryo	: 2-3%	
	Endosperm	: 89-94%	
Rice (embryo) General	Epiblast	: 0.26%	69
	Coleorniza	: 0.18%	
	Plumule	: 0.34%	
	Radicle	: 0.18%	
	Scutellum	: 1 : 4	
Sorghum General	Grain to sticks ratio	: 20% : 80%	19,38,169
CSH-9	Straw m.c.	: 10.1% (db)	
	Grain m.c.	: 8.2% (db)	
	Straw grain ratio	: 1 : 3	

	Primary Rachi/ear	Secondary Rachi/ear	Grains per year	Yield per plant, g	Kernel fraction, %		
					Husk	Germ	Endo-sperm
CSH—1	—	—	—	—	7.5	7.5	85.0
CSH—5	52.3	294	1602	—	6.2	7.3	86.5
CSH—6	—	—	—	—	7.5	5.7	86.8
CSH–9	—	—	—	—	6.9	7.8	85.3
Local	—	—	—	227.9	—	—	—
SPV-351	—	—	—	—	10.3	4.9	84.8
SPV-462	52.0	314	1730	—	—	—	—

Table Contd...

	Grains/Year	Grain, %	Straw, %	Reference
Wheat				
A—206	21.1	—	—	58, 117, 152, 160
HD—65	19.4	—	—	
HD—1553	—	40.0	60.0	
HD—1593	—	40.0	60.0	
HD—2189	—	41.7	58.3	
HD—2278	—	41.7	58.3	
HD—5439	—	38.5	61.5	
Malvi local	14.1	—	—	
Meghdoot	17.6	—	–	
Pissi Local	18.0	—	—	
	Constituents			
General	Grain to straw ratio =1 : 1.5 Germ : 3.0%; Bran : 12..0% Endosperm : 85%			
HD 4530	Straw m.c : 5.5% (db) Grain m.c : 9.1% (db) Straw to grain ratio = 1 : 0.78			
Lok—1	Grain to crop ratio = 1 : 2.22 – 1 : 1.85 Grain m.c : 5.5—7.3% (db)			
Sonalika	Grain to crop ratio = 1 : 2.6 – 1 : 2.22 Grain m.c : 7.8—8.2% (db)			

Table 1.2 : Physical constituents of pulses

Crop/Variety	Constituents	Reference
Bengal gram		
General	Grain to staw ratio=1 : 2; Cotyledon to grain ratio : 87.0 to 85.5; Testas : 15-20% of whole seed	32
H-205	Grain to crop ratio : 0.43-0.48; Moisture content of grain: 7.5-8.6%(db)	
Radhey	Moisture content of grain: 8.5% (db); Moisture content of straw: 9.6% (db); Straw grain ratio: 1.04; Grain to crop ratio= 50:100%	
Black gram		
General	Cotyledon to grain ratio: 88.0	104,173
Local	Dry matter: 90%	
Cluster bean		
Local	Plant height: 820-867 mm; No. of branches per plant: 4-5; No. of cluster/plant: 8-11; No. of seeds/pod: 8; No. of pods/plant: 28	93
Cowpea		
Local	Plant height: 242 mm; No. of cluster/plant : 12; No. of pods/plant: 26; No. of seeds/pod: 10	39
Green gram		
General	Cotyledon to grain ratio: 88.0	31
Horse gram		
Local	Dry matter: 92.5%	173
Lentil		
General	Cotyledon to grain ratio: 88.5	173
Local	Dry matter: 89.6%	
Pea		
EC-4108	Pods per plant: 35; Seed per plant: 43; Seed yield per plant: 127 g	115
General	Grain fraction (kernel: 89%; hull:11.0%)	
IC-4604	Pods per plant: 23; Seed per plant: 51; Seed yield per plant: 117 g	24,102
Pigeon pea		
C-11	No. of pods per plant: 42; Dry matter per plant: 13.7 g	24,102,104
General	Grain to stubble ratio=1:3; Cotyledon to grain ratio: 85.0 to 88.5	
Hy-3C	No. of pods per plant: 40; Dry matter per plant: 12.2 g	
ICPL-87	Grain to crop ratio=41:100%, Grain m.c: 8.8% (db); straw m.c. : 8.3% (db)	
Local	Plant height: 1,610-2,030 mm; No. of pods per plant: 88- 129; Dry matter per plant: 89.9%	
Type-21	Grain to crop ratio: 0.20-0.29; Moisture content of grain: 7.4-7.9% (db)	
UPAS-120	Stalk to grain ratio: 1.8-3.8	

able 1.3 : Physical constituents of oilseeds

rop/variety	Constituents	Reference
roudnut		
General	Pods per plant: 17-19; Kernels per pod: 2-3; Pod moisture content: 7.8% (db); Pod fractions (kernel = 70%; hull: 30%); Kernels to straw ratio = 1:1	68
oundnut (pod)		
JL–24		

Pod type	Moisture content, % (db)	Constitutents, %		
		Hull	Kernel	
			Skin	Cotyledons
Single kernel ellipsoid	7.6	21.5	2.6	75.9
Double kernel ellipsoid	7.6	22.8	1.3	75.9
Paired ellipsoid	6.8	23.8	2.2	74.0
Cassinoids	8.9	24.1	2.4	73.5
Triple kernel ellipsoid	7.5	23.2	1.9	74.9

inseed		123
ILS-73-25	No. of primary branches/plant: 3; Capsules per plant: 14; Dry matter yield per plant: 2.3 g	
ILS-169	No. of primary braches/plant:3; Capsules per plant: 20; Dry matter yield per plant: 2.3 g	
ILS-252	No. of primary braches/plant: 4; Capsules per plant:21; Dry matter yield per plant: 1.9 g	
Mustard		4,56,104, 156, 162
Kranti	Silique per plant: 383; Seeds per silique: 11; Grain yield per plant: 9.4 g	
Krishna	Silique per plant: 368; Seeds per silique: 12; Grain yield per plant: 8.9 g	
Pusa bold	Grain to crop ratio : 25.8 to 100%; Grain m.c.: 2.8% (db); Straw m.c. : 3.1% (db)	
RH-78	Plant height: 172 mm; Primary branches per plant: 5; Secondary branches per plant: 8; Silique/plant: 214; Grain yield per plant: 11.8 g	
RK-14	Silique/plant: 352; Seeds per silique:9; Grian yield per plant: 7.6 g	
Varuna	Plant height:185 mm; Primary branches/plant:4; Secondary braches per plant: 7; Silique/plant: 205; Grain yield per plant: 13.9	
Vasdan	Silique/plant: 422; Seeds per silique: 11; Grain yield per plant: 10.4 g	
Niger		
GA-5	Plant height: 1,880 mm; Branches per plant: 12; Capsules per plant: 42	159
GA-23	Plant height: 1,753 mm; Branches per plant: 9; Capsules per plant: 36	
Local	Plant height: 1,605 mm; Branches per plant: 13; Capsules per plant: 41	
N-35	Plant height: 1,733 mm; Branches per plant: 12; Capsules per plant: 59	

Table Contd...

Crop/Variety	Constituents	Reference
N-71	Plant height: 1,730 mm, Branches per plant: 12; Capsules per plant: 44	
Safflower		94
General	Plant height: 1,220-1,423 mm; Total number of branches per plant: 40-66; Yield per plant: 46.1-71.8 g; Pod moisture content: 5.3-5.8% (db); Seed fractions (kernel: 48-51%; hull:49-52%)	
JSF-1	Seed moisture content: 4.0% (db); Seed fraction (kernel: 54%; hull: 46%)	
Thin varieties	Seed fraction (kernel: 55-70%; hull: 30-45%)	
Sesamum		57
General	Plant height: 570-790 mm; No. of capsules per plant: 8-28	
Soybean		135,149,171
General	Plant height: 200-613 mm; Branches per plant: 4-7; Pods per plant: 70-164; Seeds per plant: 93-286; Seed yield per plant: 12.3-25.8 g; Cotyledon to grain ratio: 89 to 90; Seed fractions (kernel: 89%; hull: 11%)	
Bragg	Plant height : 299 mm; No. of branches/plant: 1; Stem diameter: 5.1 mm; No. of pods/plant: 31; Grain to straw ratio=1 : 1.8	
JS-2	Plant height: 198.5 mm; No. of branches/plant:1; Stem diameter: 5.0 mm; No. of pods/plant: 39; Grain to straw ratio=1 : 2.4	
JS-7244	Plant height : 445 mm; No. of branches/plant: 2; Stem diameter: 5.4 mm; No. of pods/plant: 72; Straw moisture content: 10.6% (db); Seed moisture content: 9.8% (db); Grain to straw ratio= 1 : 2.7	
JS-7546	Plant height: 570.2 mm; No. of branches/plant: 1; Stem diameter: 6.1mm; No. of pods/plant: 59; grain to straw ratio= 1: 1.2	
Punjab-1	Plant height: 473.9 mm; No. of branches/plant: 2; Stem diameter: 5.5 mm; No. of pods/plant: 74; Grain to straw ratio: 1 : 1.2; Grain to crop ratio: 34.5 to 100 %; Grain m.c. = 9.8% (db); Straw m.c.: 14.8% (db)	
Sunflower		173
Co-1	Plant height: 678 mm; No. of leaves/plant: 19; Dia. of Capitulum: 78 mm; No. of seeds (outer portion: 97; middle portion: 50; inner portion: 29); Seed yield (outer: 2.3g; middle: 1.8g; inner:1.2 g); No. of seeds per capitulum: 176; Seed yield per capitulum: 5.3 g	
Co-2	Plant height : 1,446 mm; No. of leaves/plant: 32; Dia. of capitulum: 116mm; No. of seeds (outer portion: 204; middle portion: 142; inner portion: 127); Seed yield (outer: 8.9 g; middle: 5.3 g; inner: 5.3 g); No. of seeds per capitulum: 473; Seed yield/capitulum: 19.6 g	
EC-68414	Pod moisture content: 7.5% (db); Capitulum fraction (kernel: 23.8%; husk: 76.2%)	
EC-68415	Pod moisture content: 7.5% (db); Capitulum fraction (kernel: 23.3%; 76.7%)	
General	Seed fractions (kernel: 70%; hull: 30%)	
Morden	Capitulum fraction (kernel: 28.6%; husk: 71.4%); Seed fraction (kernel: 70.4%; hull: 29.6%)	
TNAU-SUF-4	Plant height: 1,363 mm; No. of leaves/plant: 31; Dia. of capitulum: 121.5 mm; No. of seeds (outer portion: 185; middle portion: 122; inner portion: 103); Seed yield (outer: 7.2 g; middle: 4.5 g; inner: 4.5 g); No. of seeds per capitulum: 410; Seed yield per capitulum: 15 g	

ble 1.4 : Physical constituents of some fruits, spices and other crops

op/Variety	Constituents	Reference
nana		
C.V.Basrai	Plant height: 1,663-1,688 mm; Plant girth: 603-611 mm; Total leaves per plant: 45; Bunch weight: 1,050-1,090 g; Fruits per bunch: 106-108	139
ardamom		
Malabar	Moisture content: 8.7%(db); Seed to husk ratio=1 : 0.40	46
Mysore	Moisture content: 7.8% (db); Seed to husk ratio= 1 : 0.35	
Local	No. of seeds per capsule: 13; Capsule weight: 0.2 g; Capsule fraction (seed: 32%; skin: 68%); Seed recovery: 67.5%	
Vazhukka	Moisture content: 11.1% (db); Seed to husk ratio= 1 : 0.33	
arrot		
General	Water content: 86-89%	57
ashewnuts		
General	Kernel: 25%, Shell: 75%	3
assava		
Local	Tuber to stem ratio =1 : 1; Moisture content of tuber : 150% (db); Leaves: 6%; Stem: 44%; Tuber: 50%	57
love	Weight of clove: 0.07-0.09 g	88
oconut		
Seedling	Girth: 155 mm; Height: 154 mm; Total no. of leaves: [illegible]; Seedling weight: 2,370 g	57
Tree	Height: 4,970 mm; Girth: 810 mm; No. of functional leaves: 32	
oriander seed		
Local	Kernel : 56.8%; Hull : 43.2% at 10.4% (db) moisture content of coriander seed	172
urry leaf		
DWD-1	Shoot length : 81 mm; No. of leaves per shoot: 8; No. of leaflets per leaf: 9; Girth of shoot at base :1.6 mm; Internodal length at base of shoot: 5.4 mm	85
DWD-2	Shoot length: 312 mm; No. of leaves per shoot: 16; No. of leaflets per leaf: 20; Girth of shoot at base : 3.8 mm; Internodal length at base of shoot : 24 mm	
rape		
General	Bud load per vine: 36-120 kg	25,176
inseed stalk fibre	Tenacity: 22.896 ± 2.16 g/tex; Fineness: 4.016 ± 0.126 tex; Colour percentage : 50.16; Bulk density : 4.025 g/cm^3; Lusture : 0.993	22
ongmelon seed		
Local	Kernel : 68; Hull: 32%	127
ango		
Local	Pulp content : 61%; Stone content : 21%; Peel content : 18%	57
ango stone	Kernel content : 57%; Pericarp content : 43%	173
uskmelon seed		
Local	Kernel : 75%; Hull : 25%	127
utmeg fruit		
General	Pericarp : 81-82%; Seed: 16-17%; Aril surrounding the seed : 2-2.5%; Length : 20-35 mm; Diameter : 15-28 mm	88

Table Contd...

Crop/Variety	Constituents	Referen
Oil Palm		
General	Plant height : 20,000-30,000 mm; Fruit per bunch : 500-2,000; Weight of fruit : 3-30 g; Age of tree : 100 or more years	17
Peach		
Tesia Samisto	Fruit weight : 54.1-79.5 g	11
Pomegranate		
Local	Weight per seed : 12-25 mg; Weight of testa (as on whole seed weight) : 50-57%	12
Potato		
Kufri Jyoti	Plant height : 383 mm; Tubers weight per hill : 182.7 g	100,144,15
Local	Plant height : 377-415 mm; No. of leaves per plant : 42-65; Stems per plant : 3-5; Tubers per plant : 6-12; Weight of tubers per plant : 282-543 g; Tubers weight per hill : 229-259 g	
SS/C-562	Plant height : 363 mm; Tubers weight per hill : 179.7 g	
SS/C-1101	Plant height : 364 mm; Tubers weight per hill : 166.0 g	
Sugarcane		
CO-1148	Juice content : 62.7% at 8 months; 62.7% at 10 months; 59.2% at 12 months	3,10
CO-7314	Juice content : 61.2% at 8 months; 60.9% at 10 months; 57.6% at 12 months	
CO-7717	Juice content : 61.8% at 8 months; 66.8% at 10 months; 58.3% at 12 months	
CO-J64	Juice content : 61.7% at 8 months; 61.9% at 10 months; 57.5% at 12 months	
General	Water content : 73-76%; Solids content : 24-27%; Cane-thresh (leaves and portion of the top of stalk) from cane harvested: 10%	
Sweet potato		
Jawahar-145	Moisture content of fresh tuber : 217.5% (db); Moisture content of dry tuber : 5.4% (db)	57
Water chest-nut		
Red and White	Moisture content of fresh kernel : 115.3-114.3% (db); Moisture content of dry kernel : 7.5-10.9% (db)	173

Table 1.5 : Chemical constituents of cereals

Crop/Variety	Constituents	Reference
Barley		99, 151
Local	Crude protein : 11.5%; Fat : 1.5%; Crude fibre : 7.5%	
Finger millet		21
CO-11	Protein : 7.5%; Carbohydrate : 76.0%; Starch : 62.0%	
Godavari	Ash : 2.6%, Nitrogen : 1.3%; Phosphorus : 29.5%; Iron : 6%	
Maize (corn)		112,151
Local	Crude protein : 9.0-9.8%; Ash : 1.7-2.1%; Carbohydrate : 62.5-65.4%; Crude fibre : 2.0-2.4%	
Local (kernel dry)	Carbohydrate : 80%; Protein : 10%; Oil : 4.5%, Fibre : 3.5%; Minerals: 2.0%	
Oats		151
Local	Crude protein : 9.5%; Fat : 4.0%; Crude fibre : 12.0%	
Pearmillet		30
CO-6	Ash : 1.4%; Protein : 9.5%	
CO-7	Ash : 1.4%; Protein : 12.9%	
Local	Ash : 2.7%; Protein : 11.9%; Carbohydrate : 59.2%	
WCC-75	Ash : 1.2%; Protein : 10.3%	
X4	Protein : 12.0%; Carbohydrate : 70.0%; Starch : 60.0%; Amylose : 18.4%; Amylopectin : 41.6%	
Prosomillet (common millet/Baragu)		
BR-7	Protein : 10.2%; Fat : 2%; Ash : 4.1%; Tannin : 84.2 mg/100g; Amylose : 20.2 mg/100g; Starch : 50.2 mg/100g; Sugar : 55.8 mg/100g	18
CO-1	Protein ; 6.8%; Ash : 3.4%; Calcium : 26.4 mg/100g; Phosphorous : 164.8 mg/100g; Tannin : 115.4 mg/100g; Amylose: 13.2 mg/100g; Starch : 49.1 mg/100g; Sugar : 54.6 mg/100g	
CO-2	Protein : 19.0%; Ash : 3.9%, Tannin : 92.7 mg/100g; Amylose: 21.8 mg/100g; Starch : 48.7 mg/100g; Sugar : 54.2 mg/100g	
K-2	Protein : 7.3%; Ash : 3.7%; Calcium : 30.7 mg/100g; Phosphorous : 112.5 mg/100g; Tannin : 123.7 mg/100g; Amylose: 19.1 mg/100g; Starch : 53.3 mg/100g; Sugar : 58.3 mg/100g	
Raum-11	Protein : 14.9%; Fat : 1.8%; Ash : 3.3%, Calcium : 26.2 mg/100g; Phosphorous : 163.6 mg/100g; Tannin : 92.7 mg/100g; Amylose : 14.2 mg/100g; Starch : 51.7 mg/100g; Sugar : 61.2 mg/100g	
Rice (brown)		
Jaha	Protein : 7.2%; Reducing sugar : 0.42%; Amylose : 18.3%; Fat: 2.6%; FFA : 31.3 mg KOH/100 g	134
Manoharsali	Protein : 6.3%; Reducing sugar : 0.40%; Amylose : 19.2%; Fat : 2.2%; FFA : 37.5 mg KOH/100 g	
General range	Protein (N x 5.95) : 7.1-13.1%; Crude fat : 1.8-4.0%; Dietary fat : 0.2-2.6%; Ash : 1.0-2.4%; Nitrogen-free extract : 74.5-90.2%	
Rice (embryo)		
General range	Protein (N x 5.95) : 17.7-24.1%; Crude fat : 15.2-23.8%; Dietary fat : 2.0-4.8%; Ash : 6.1-10.1%; Nitrogen-free extract: 36.2-57.3%	134
Rice (kani)		
Local	Crude protein : 8.0%; Fat : 1.7%; Crude fibre : 1.4%	134
Rice (milled)		

Table Contd...

Crop/Variety	Constituents	Reference
CO-33	Protein : 10.1%; Carbohydrate : 81.9%	134
General range	Protein (N x 5.95) : 5.6-13.3%; Crude fat : 0.2-1.1%; Dietary fat : 0.1-0.6%; Ash : 0.3-0.7%; Nitrogen-free extract : 84.0-93.5%	
Jaha	Protein : 6.7%; Reducing sugar : 0.31%; Amylose : 19.7%; Fat: 1.7%; FFA : 26.0 mg KOH/100 g	
Manoharsali	Protein : 6.1%; Reducing sugar : 0.20%; Amylose : 20.9%; Fat: 1.1%; FFA: 30.6 mg KOH/100 g	
Prasadbhog	Protein : 6.0%; Reducing sugar : 0.31%; Amylose : 20.4%; Fat: 1.4%; FFA : 20.4 mg KOH/100 g	
Rice (bran)		134
General range	Protein (N x 5.95) : 12. 1-17. 2%; Crude fat : 14.6-21.7%; Dietary fat: 8.7-13.1%; Ash; 9.0-12.12%; Nitrogen-free extract : 40.9-49.1%	
Jaha (bran yield : 3.9%)	Protein : 12.1%; Fat : 18.6%; FFA : 279.2 mg Koh/100 g	
Manoharsali (bran yield : 4.9%)	Protein : 11.8%; Fat: 19.5%; FFA : 234.3 mg KoH/100 g	
Prasadbhog (bran yield : 3.9%)	Protein : 11.2%; Fat : 18.0% FFA : 216.8 mg KoH/100g	
Rice (huller bran)	Protein : 5-7%; fibre : 20-35%; Ash : 16%; oil content : 3-4%; Silica : 15-20%	134
Rice (polish) General range	Protein (Nx 5.95) : 12.8-16.4%; Crude fat : 8.8-15.3%; Dietary fat : 2.1-5.3%; Ash : 5.0-9.3%; Nitrogen-free extract : 53.7-71.3%	134
Sorghum		7,15
CO-18	Crude Protein : 9.1%; Carbohydrate : 74.5%; Tannin : 0.40%; Lysine : 0.24%	
CO-21	Crude Protein : 8.8%; Carbohydrate : 72.4%; Tannin : 0.35%; Lysine : 0.26%	
CSH-1	Crude Protein : 8.4%; Fat : 2.4%; Crude fibre: 1.5%; Ash : 1.4%; Carbohydrate : 77.4%	
CSH-5	Crude protein : 8.9%; Fat : 2.2%; Crude fibre : 1.4%; Ash : 1.4-1.7%; Calcium : 0.32%; Carbohydrate : 76.2%; Phosphorus : 0.25%	
CSH-6	Crude protein : 8.4%; Fat : 2.3%; Crude fibre : 1.4%; Ash: 1.2-1.6%; Calcium: 0.36%; Carbohydrate: 75.9%; Phosphorus: 0.26%	7,151
CSH-8R	Ash: 1.4%; Calcium: 0.32%; Phosphorus: 0.28%	
CSH-9	Crude protein : 8.2%; Fat : 2.5%; Crude fibre : 1.8%; Ash: 1.5-1.8%; Calcium: 0.44%; Carbohydrate: 75.4%; Phosphorus: 0.30%	
D-340	Ash: 1.8%; Calcium: 0.32%; Phosphorus: 0.25%	
Local	Moisture content: 9.0%(db); Crude Protein: 10.0-10.4%; Fat: 2.8-3.2%; Crude fibre: 2.0%; Nitrogen: 1.7%	
Moti	Ash: 1.7%; Calcium: 0.40%; Phosphorus: 0.25%	
M-35-1	Ash: 1.8%; Calcium: 0.44%; Phosphorus: 0.23%	
N-1	Ash: 1.5%; Calcium: 0.40%; Phosphorus: 0.22%	
N-131	Ash: 1.6%; Calcium: 0.36%; Phosphorus: 0.20%	
PJ-837	Ash: 1.4%; Calcium: 0.44%; Phosphorus: 0.18%	
PJ-840	Ash: 1.4%; Calcium: 0.36%; Phosphorus: 0.20%	
PJ-842	Ash: 1.5%; Calcium: 0.32%; Phosphorus: 0.22%	
PJ-845	Ash: 1.3%; Calcium: 0.36%; Phosphorus: 0.22%	

Table Contd...

Crop/Variety	Constituents	Reference
PJ-868	Ash: 1.8%; Calcium: 0.36%; Phosphorus: 0.22%	
SPV-86	Ash: 1.6%; Calcium: 0.40%; Phosphorus: 0.23%	
SPV-126	Ash: 1.5%; Calcium: 0.48%; Phosphorus: 0.30%	
SPV-168	Ash: 1.6%; Calcium: 0.40%; Phosphorus: 0.28%	
SPV-221	Ash: 1.8%; Calcium: 0.44%; Phosphorus: 0.31%	
SPV-346	Ash: 1.8%; Calcium: 0.40%; Phosphorus: 0.28%	
SPV-351	Crude Protein: 7.9%; Fat: 3.2%; Crude Fibre: 2.1%; Ash: 1.5-1.9%; Calcium: 0.36%; Carbohydrate: 74.2%; Phosphorus: 0.26%	
SPV-386	Ash: 1.6%; Calcium: 0.44%; Phosphorus: 0.26%	
SPV-422	Ash: 1.5%; Calcium: 0.40%; Phosphorus: 0.22%	
Swarna	Ash: 1.7%; Calcium: 0.48%; Phosphorus: 0.26%	
Wheat (Chapati)		
Local	Moisture content: 5.6%(db); Crude protein: 10.9%; Crude fat: 1.1%; Crude fibre: 1.2%; Ash: 2.9%	118,140,155
Wheat (Dalia)		
Aestivam	Moisture content: 11.1-11.2%(db); Dry gluten: 8.4-8.8% (dry wt. basis); Ash : 1.6-1.7% (total) : 0.08-0.14 (insoluble); Pigments: 3.0-3.8 ppm (dry wt. basis)	118
Wheat (grain)		
C-306	Moisture content: 9.2%(db); Ash: 1.6-1.9%; Crude protein: 8.8-9.8%; Crude fibre: 2.6%; Crude fat: 1.6%; Carbohydrate: 87.9%; Calcium: 89.9 mg/100 g; Phosphorus: 149.4 mg/100g	117,118,160
HD-2009	Moisture content: 7.7%(db); Ash: 1.6%; Crude protein: 10.1%; Crude fibre: 1.1%; Calcium: 77.5 mg/100 g; Phosphorus: 174.4 mg/100g	
HD-2204	Ash: 1.6%; Crude protein: 12.3%; Crude fibre: 4.1%; Crude fat: 1.7%; Carbohydrate: 84.5%	
Kalyan Sona	Moisture content: 7.6%(db); Ash: 1.7%; Crude protein: 9.6%; Crude fibre: 1.2%; Calcium: 64.2 mg/100 g; Phosphorus: 179.9 mg/100g	
Sonalika	Moisture content: 14.5%(db); Ash: 1.1%; Crude protein: 10.9%; Gluten: 37.3% (wet) : 11.5% (dry)	
UP-301	Moisture content: 12.7%(db); Ash: 1.4%; Crude protein: 11.6%; Gluten: 35.3% (wet) : 11.5% (dry)	
WH-147	Moisture content: 7.5%(db); Ash: 2.0%; Crude protein: 8.9%; Crude fibre: 1.1%; Calcium: 139.1 mg/100g; Phosphorus: 373.3 mg/100g	
WH-157	Moisture content: 8.2%(db); Ash: 1.9%; Crude protein: 12.1%; Crude fibre: 1.2%; Calcium: 89.1 mg/100 g; Phosphorus: 242.2 mg/100g	
WL-711	Moisture content: 7.9%(db); Ash: 1.8%; Crude protein: 9.7%; Crude fibre: 1.4%; Calcium: 74.9 mg/100 g; Phosphorus: 191.1 mg/100g	
Wheat (straw)	Crude protein: 2.9-3.5%; Crude fibre: 34.6-39.6%; Cellulose: 37.4-41.6%	160

Table 1.6 : Chemical constituents of pulses

Crop/Variety	Constituents	Reference
Bengal gram (edible portion)		
General	Water: 11.0%; Protein: 20.1%; Oil: 4.5%; Fibre: 4.9%; Carbohydrate: 56.6%; Ash: 2.9%; Calories: 358 kcal/100 g	151
Local	Dry matter: 92.0%; Protein: 18.7%; Oil: 4.5%; Carbohydrate (soluble): 58.0%; Fibre: 0.2%; Total mineral matter: 3.6%	
Black gram		
CO-4	Protein: 21.7%; Carbohydrate: 58.0%; Free amino acid: 15.3 mg/100g	151
Black gram (edible portion)		
Local	Dry matter: 90.0%; Protein: 19.3%; Oil: 0.7%; Carbohydrate (soluble): 62.4%; Fibre: 0.5%; Total mineral matter: 7.1%	151
Cowpea	Water: 11.0%; Protein: 23.4%; Oil: 1.8%; Fibre: 4.3%; Carbohydrate: 56.0%; Ash: 3.5%; Calories: 342 kcal/100g	151
Fababean		
General	Water: 11.0%; Protein: 23.4%; Oil: 2.0%; Fibre: 7.8%; Carbohydrate: 52.4%; Ash: 3.4%; Calories: 348 kcal/100 g	42,151
JB-33	Moisture content: 12.7%(db); Ash: 3.0%; Protein: 26.6%; Oil: 1.5%; Crude fibre: 2.8%; Carbohydrate: 56.9%; Starch: 55.4%; Free soluble sugar: 1.4%	
JV-1	Moisture content: 11.6%(db); Ash: 3.0%; Protein: 24.9%; Oil: 1.4%; Crude fibre: 2.5%; Carbohydrate: 55.8%; Starch: 54.2%; Free soluble sugar: 1.3%	
JV-6	Moisture content: 12.5%(db); Ash: 3.1%; Protein: 26.1%; Oil: 2.4%; Crude fibre: 3.2%; Carbohydrate: 57.6%; Starch: 56.0%; Free soluble sugar: 1.4%	
JV-7	Moisture content: 12.6%(db); Ash: 3.1%; Protein: 26.8%; Oil: 1.9%; Crude fibre: 3.2%; Carbohydrate: 58.2%; Starch: 56.7%; Free soluble sugar: 1.4%	
JV-17	Moisture content: 12.5%(db); Ash: 3.1%; Protein: 25.4%; Oil: 2.4%; Crude fibre: 3.1%; Carbohydrate: 56.9%; Starch: 55.5%; Free soluble sugar: 1.4%	
JV-18	Moisture content: 12.2%(db); Ash: 2.8%; Protein: 25.0%; Oil: 2.3%; Crude fibre: 3.8%; Carbohydrate: 56.9%; Starch: 55.5%; Free soluble sugar: 1.3%	
JV-70	Moisture content: 11.8%(db); Ash: 2.9%; Protein: 23.1%; Oil: 1.21%; Crude fibre: 2.6%; Carbohydrate: 55.8%; Starch: 59.4%; Free soluble sugar: 1.6%	
JV-89	Moisture content: 12.9%(db); Ash: 3.0%; Protein: 25.7%; Oil: 2.3%; Crude fibre: 2.9%; Carbohydrate: 56.4%; Starch: 54.9%; Free soluble sugar: 1.4%	
JV-7081	Moisture content: 11.5%(db); Ash: 2.8%; Protein: 24.7%; Oil: 1.4%; Crude fibre: 3.6%; Carbohydrate: 56.4%; Starch: 54.8%; Free soluble sugar: 1.4%	
Whole Faba bean		
Winter crop	Moisture: 14.1%; Ether extract: 0.95%; Protein (Nx 6.25):23.3%; Crude fibre: 7.05%; Ash: 3.5%; N-free extract: 51.1%; Calcium: 0.08%; Average phosphorus: 0.1%; Salt: 0.8%	151

Table Contd...

Spring crop Moisture: 11.8%; Ether extract: 1.0%; Protein (Nx 6.25):27.7%;

Crop/Variety	Constituents	Reference
	Crude fibre: 6.30%; Ash: 3.5%; N-free extract: 49.7%; Calcium: 0.08%; Average phosphorus: 0.1%; Salt: 0.8%	
Dehulled Faba bean (testas removed)		
Winter crop	Moisture: 14.9%; Ether extract: 1.02%; Protein (Nx 6.25):25.3%; Crude fibre: 2.95%; Ash: 3.5%; N-free extract: 52.3%; Calcium: 0.03%; Average phosphorus: 0.1%; Salt: 0.7%	151
Spring crop	Moisture: 12.3%; Ether extract: 1.08%; Protein (Nx 6.25):30.5%; Crude fibre: 2.07%; Ash: 3.5%; N-free extract: 50.6%; Calcium: 0.03%; Average phosphorus: 0.1%; Salt: 0.7%	
Green gram		
M-2	Protein: 20.96%; Carbohydrate: 60.0%; Free amino acid: 13.6 mg/100 g	151
Green gram (edible portion)		
Local	Dry matter: 89.6%; Protein: 21.2%; Oil: 1.1%; Carbohydrate: (soluble: 59.6%; fibre: 3.8%); Total mineral matter: 4.1%	151
Horse gram		
Local	Moisture content: 11.1%(db); Protein: 26.0%; Crude fat: 0.98%; Carbohydrate: 52.9%; Mineral matter: 3.5%	151
Horse gram (dhal)	Moisture content: 10.7%(db); Protein: 26.6%; Crude fat: 1.4%; Carbohydrate: 56.2%; Mineral matter: 5.0%	151
Horse gram (edible portion)		
Local	Dry matter: 92.5%(db); Protein: 23.4%; Oil: 0.9%; Carbohydrate: (soluble: 58.4%; fibre: 4.6%); Total mineral matter: 4.8%	151
Horse gram (germinated)		
Local	Moisture content: 9.2%(db); Protein: 25.9%; Crude fat: 1.3%; Carbohydrate: 52.9%; Mineral matter: 4.2%	151
Lentil	Water: 11.0%; Protein: 24.2%; Oil: 1.8%; Fibre: 1.8%; Carbohydrate: 59.0%; Ash: 2.2%; Calories: 346 kcal/100g	151
Lima beans		
General	Water: 12.7%; Protein: 21.4%; Oil: 1.4%; Carbohydrate: 61.1%; Fibre: 4.3%; Ash: 3.4%; Calories: 335 kcal/100 g; Calcium: 116.0 mg/100g; Thiamine: 0.33 mg/100g; Iron: 4.9 mg/100g; Riboflavin: 0.16 mg/100g; Niacine: 2.1 mg/100 g	151
Pea		
General	Water: 11.0%; Protein: 22.5%; Oil: 1.8%; Fibre: 5.5%; Carbohydrate: 53.7%; Ash: 5.5%; Calories: 346 kcal/100g	151
Local	Moisture content: 14.4-19.2%(db); Crude fibre: 3.9-6.3%; Ash: 2.9-4.0%; Crude protein: 15.0-29.4%; Crude fat: 1.2-2.6%; Carbohydrate: 58.6-73.8%	
Dried	Water: 13.3%; Carbohydrate: 50.0%; Fat: 1.3%; Protein: 21.6%; Nitrogen: 3.45%; Na: 38 mg/100g; K: 990 mg/100g; Ca: 61 mg/100g; Mg: 116 mg/100g; P: 300 mg/100g; Fe: 47 mg/100g; Cu: 0.5 mg/100g; Zn: 3.5 mg/100g; S: 130 mg/100g; Cl: 60 mg/100g	

Table Contd...

Crop/Variety	Constituents	Reference
Fresh	Water: 78.5%; Carbohydrate: 10.6%; Fat: 0.4%; Protein: 5.8%; Nitrogen: 0.9%; Na: 1.0 mg/100g; K: 340 mg/100g; Ca: 15 mg/100g; Mg: 30 mg/100g; P: 100 mg/100g; Fe: 1.9 mg/100g; Cu: 0.2 mg/100g; Zn: 0.7 mg/100g; S: 2.0 mg/100g; Cl: 3.9 mg/100g	
Pigeon pea		
Co-11	Crude protein: 18.9%	167
Co-33	Crude protein: 21.2%, Carbohydrate: 57.4%; Free amino acid: 13.0 mg/100g	
Local	Moisture content: 14.2%(db); Ash: 4.8%; Crude fibre: 7.1%; Crude protein: 22.6%; Crude fat: 2.7%; Carbohydrate: 62.9%; Total sugar: 7.5%; Dry matter: 89.9%; Oil: 1.3%; Total mineral matter : 3.8%	
No. 148	Crude protein: 24.9%	
T-vishaka	Crude protein: 22.8%	
Pigeon pea (husk)	Dry matter: 92.2%; Protein: 8.4%; Oil: 1.5%; Carbohydrate: (soluble: 41.9%; Fibre: 35.1%); Total mineral matter: 5.3%	167
Pigeon pea (split)	Moisture content: 17.9%(db); Protein: 22.3%; Fat: 1.7%; Carbohydrate: 57.2%; Ash: 3.6%	167
Winged beans		
General	Protein: 21-46%; Oil: 7-22%; Crude fibre: 9-11%; Nitrogen- free extract: 24-28%	57

Table 1.7 Chemical constituents of oilseeds and oil cake

Crop/Variety	Constituents	Reference
Castor seed		
General	Oil content: 45-52%; Protein: 12-16%; Soluble sugar: 3-7%; Fibre: 23-27%; Minerals: 2.0%	111
Castor cake		
General	Protein: 20-25%; Crude fibre: 40-45%; Carbohydrate 15%	111
Coconut		
General	Oil content : 62% in copra	3
Cotton seed		
General	Oil content : 14-18%	3
Groundnut		
POL-2	Protein: 23.2%; Oil content: 41.5%	111
Spanish bunch	Oil content: 48.7%; Protein: 22.9%; Soluble sugar: 9.8%; Energy value: 2,676 J/100 g	
TMV-7	Oil content: 40.2%; Protein: 22.3%	
Valencia	Oil content: 47.2%; Protein: 23.7%; Soluble sugar: 7.9%; Energy value: 2,645 J/100 g	
Virginia bunch	Oil content: 51.4%; Protein: 23.0%; Soluble sugar: 9.8%; Energy value: 2,708 J/100 g	
Virginia runner	Oil content: 47.2%; Protein: 23.6%; Soluble sugar: 11.6%; Energy value: 2,646 J/100 g	
Linseed		
General	Oil content: 37.8-47.7%; Protein: 11.1-31.9%	111
Mahua seed		
General	Oil content : 36%	3
Mustard/rapeseed		
General	Oil content: 37.6-43.9%; Protein: 22-34%; Ash: 6.0- 7.8%; Iodine value: 100.2-101.5; Refractive index at 40°C : 1.4604-1.4627	6,88
Mustard (meal)	Carbohydrate: 35%	128
Neem seed		
General	Oil content : 45-50%	3
Niger seed		
CHH-1	Moisture content: 7.4%(db); Oil content: 47.0%; Ash: 4.6%; Protein: 36.4%; Iodine value: 127.8; Saponification value: 198.8; FFA: 1.9%; Refractive Index: 1.4717	128
General	Oil content: 30.0-32.4%; Crude protein: 26.0-30.6%	
IGP-76	Moisture content: 6.6%(db); Oil content: 46.4%; Protein: 35.7%; Ash: 4.3%; Iodine value: 125.9; Saponification value: 196.5; FFA: 2.0%; Refractive Index: 1.4731	
N-5	Moisture content: 4.4%(db); Oil content: 41.6%; Protein: 38.7% Ash: 4.2%; Iodine value: 126.4; Saponification value: 195.0; FFA: 1.5%; Refractive Index: 1.4734	
N-35	Moisture content: 5.1%(db); Oil content: 40.3%; Protein: 37.5%; Ash: 4.6%; Iodine value: 128.4; Saponification value: 193.3; FFA: 1.8%; Refractive Index: 1.4705	
N-71	Moisture content: 5.5%(db); Oil content: 45.9%; Protein: 36.7%; Ash: 4.9%; Iodine value: 126.4; Saponification value: 194.6; FFA: 1.8%; Refractive Index: 1.4731	

Table Contd...

Crop/Variety	Constituents	Reference
Safflower		
Bhima	Oil content: 30.0%; Protein: 9.0-10.0%; Fibre: 26-27%; Mineral matter: 2.0-3.0%	128
General	Oil content: 27-35%; Protein: 13-17%; Ash: 2.0%; Total sugar: 3.2%; Crude fibre: 40.6%	
Safflower (cake/meal)		
General	Fibre: 2.9-4.0%; Phosphorus: 0.29-0.30%; Calcium: 0.29- 0.47%; Tannin: 0.52-0.74%; Energy content: 1,470-3,804, kcal/kg	128
Sesamum seed		
General	Oil content : 48.8-49.1%; Protein : 18-26%	128
Soybean		
Cocker stuart (bold)	Moisture content : 8.5% (db); Ash : 5.2%; Protein : 35.0%; Oil content : 23.1%; Crude fibre : 2.9%, Carbohydrate : 17.7%; Starch : 17.2%; Free sugar : 0.25%; Calcium : 280.0 mg/100g; Sulphur : 186.8 mg/100 g; Phosphorus : 76.6 mg/100 g	128
JS-72-44 (medium)	Moisture content : 9.3% (db); Ash : 5.6%; Protein : 34.3%; Oil content : 21.1%; Crude fibre : 2.9%; Carbohydrate : 17.4%; Starch : 16.9%; Free sugar : 0.25%; Calcium : 320.0 mg/100 g; Sulphur : 208.4 mg/100 g; Phosphours : 86.8 mg/100 g	
JS-76-205 (small)	Moisture content : 9.5%(db); Ash : 6.1%; Protein : 32.9%; Oil content : 19.9%; Crude fibre : 2.9%; Carbohydrate : 18.3%; Sulphur : 208.4 mg/100 g; Phosphorus : 86.8 mg/100 g; starch: 17.8%; Free sugar : 0.26%; Ca: 300.0 mg/100g	
Soybean (cake)	Protein : 41.0%; Fat : 3.5%; Fibre : 6.5%	128
Sunflower		
EC-68414	Oil content : 36-38%; Protein : 17-18%; Fibre : 5-6%; Mineral matter : 2-3%	
EC-68415	Oil content : 35-37%; Protein : 17-18%; Fibre : 5.5-6%; Mineral matter : 2-3%	
General	Oil content : 41.2-45.0 %; Protein : 48.5-49.3% (defatted seed)	

'able 1.8 : Chemical constituents of fruits, vegetables, spices and other crops

'rop/Variety	Constituents	Reference
,niseed		
General	Moisture content : 9.9-14.9%(db); Protein : 1.8%; Fatty oil : 8-23%; Essential oil : 2-7%; Sugar : 3-5%; Starch : 5%; Crude fibre : 12-15%; Ash : 8-10%	88
,pple		
General	Moisture content : 549.4% (db); Protein : 0.2%; Carbohydrate : 13.4%; Fat : 0.5%; Minerals : 0.3%; Fibre : 1.0%	57
3eet greens		
Local	Crude protein : 3.2%; Crude fat : 0.8%; Crude fibre : 0.3%; Ash : 1.9%	84
3eet sag		
Local	Moisture content : 5.8% (db); Crude protein : 15.6%; Crude fat: 1.7%; Crude Fibre : 1.7%; Ash : 12.8%	84
Carrot		
General	Protein : 0.8-1.0%; Fat : 0.2%; Calcium : 30-39 mg/ 100g; Magnesium : 17 mg/100 g; Phosphorus : 32-43 mg/100g	57
Celery leaves		
General	Moisture content : 434.8% (db) ; Carbohydrate : 8.6%; Fat : 0.6%; Protein : 6%	88
Celery stalks		
General	Moisture content : 1438.5% (db); Carbohydrate : 3.5%; Fat : 0.1%; Protein : 0.8%	88
Chillies		
Dry	Moisture content : 11.1% (db); Protein : 15.9%; Fat : 0.2%; Carbohydrate : 31.6%; Fibre : 30.2%; Mineral matter : 6.1%; Calcium : 0.16%; Phosphorus : 0.37%; Iron : 0.0023%; Votamin : 50 mg/100g; Vitamin E : 2.4 mg/100 g	81
Green	Moisture content : 474.7% (db); Protein : 2.9%; Fat : 0.6%; Carbohydrate : 6.1%; Fibre : 6.8%; Mineral matter : 1.0%; Calcium : 0.3%; Phosphorus : 0.8%; Iron : 0.0012%	
Chilli meal	Protein : 28.92%; Carbohydrate : 26.37%; Fibre : 29.1%; Ash: 5.61%	81
Chilli powder	Moisture content : 11.1% (db) max.; Total ash : 8% max; Acid insoluble ash : 1.25% max; Crude fibre : 30% max; Non- volatile ether extract : 12% min.	81
Chilli seeds	Moisture content : 6.7% (db); Oil : 26.1%	81
Cinnamon		
Madagaskar	Moisture content : 13.6% (db) max; Total ash : 5% max; Acid insoluble ash : 1% max; Volatile oils (whole : 1% 100 g min db; ground : 0.7% 100 g min db)	85
Srilanka	Moisture content : 13.6% (db) max; Total ash : 7% max; Acid insoluble ash : 2% max; Volatile oils (whole : 0.4% 100 g min db; ground : 0.3% 100 g min db)	
Clove		
Dried	Protein : 5.2%; Fat 8.9%; Fibre : 9.5%; Carbohydrates : 46%; Mineral matter : 5.2%	84
Coconut		
Dry	Moisture content : 4.5% (db); Protein : 6.8%; Carbohydrate: 18.4%; Fat : 62.3%; Minerals : 1.6%; Fibre : 6.6%	88,173

Table Contd...

Crop/Variety	Constituents	Reference
Fresh	Moisture content : 56.9% (db); Protein : 41.6%; Carbohydrate : 13.0%; Fat : 41.6%; Minerals : 1.0%; Fibre : 3.6%	
Coriander		
General	Moisture content : 12.6% (db); Protein : 14.1%; Carbohydrate : 21.6%; Fat : 16.1%; Minerals : 4.4%; Fibre : 32.6%	88
Cumin		
General	Moisture content : 13.5% (db); Protein : 18.7%; Carbohydrate: 36.6%; Fat : 15.0%; Minerals : 5.8%; Fibre : 12.0%	88
Curry leaf		
General	Moisture content : 199.4% (db); Protein : 6.1%; Carbohydrate : 18.7%; Vitamin A: 12600 IV; Vitamin C : 4 mg/100 g	84
Fenugreek seed		
General	Moisture content : 15.9% (db); Protein : 26.2%; Carbohydrate : 44.1%; Fat : 5.8%; Minerals : 3.0%; Fibre : 7.2%	88
Fenugreek leaves		
General	Moisture content : 614.3% (db); Protein : 4.4%; Fibre : 11.1%; Fat : 0.9%; Carbohydrate : 6%; Ash : 1.5%	88
Garlic		
Cured	Moisture content : 163.2% (db); Protein : 6.3%; Carbohydrate : 29.8%; Fat : 0.1%; Minerals : 1.0%; Fibre : 0.8%	88
Ginger		
Dry	Moisture content : 9.3-19.8% (db); Starch : 40.4-59.0%; Crude fibre : 4.79-9.80%; Crude protein : 10.3-15.0%; Oleoresin (acetone extract) : 3.9-9.3%; Oleoresin (water extract) : 14.4- 25.8%; Cold alcohol extract : 3.55-9.28%; Total ash: 5.12-9.28%; Volatile oil:1.0-2.7%	79
Grape		
General	Total soluble solids : 16.7-18.0%; Acidity : 0.378-0.407%	173
Honey	Glucose : 35%; Fructose : 40%; Sucrose : 5%	141
Mace		
Dry	Moisture : 18.9% (db); Protein : 6.5%; Ether extract : 24.4%; Carbohydrate : 47.8%	84
Mushroom	Protein : 26.4%; Carbohydrate : 44%; Free amino acid : 2.0%	11
Nutmeg		
Dry	Moisture content : 16.7% (db); Protein : 7.5%; Ether extract : 36.4%; Carbohydrate : 28.5%; Fibre : 11.6%; Mineral matter : 1.7%; Furfurol : 1.5%; Pectins : 0.5-0.6%; Volatile oil:6-16%; Starch: 14.6-24.2%; Pentosans: 2-2.5%	84
Onion		
Local	Carbohydrate : 11.0 g/100g; Protein : 1.2 g/100g; Dietery Fibre : 0.6g/100g	173
Peach		
Tesia Samisto	Total soluble solids : 10.67-11.40%; pH : 2.85-3.21	133
Pepper (black)		
Dry	Moisture content : 13.6% (db); Total ash : 5.4%; Acid insoluble ash : 0.02%; Oleoresin yield : 12.5%; Piperine : 6.5%; Piperine in oleoresin : 52.0%; Non volatile ether extract : 8.3%; Crude fibre : 15.8%	89

Table Contd...

Crop/Variety	Constituents	Reference
Fresh	Moisture : 212.5% (db); Volatile oil : 2.1%; Non volatile ether extract : 8.1%; Crude fibre : 14.1%; Ascorbic acid : 3.2 mg/100 g; Starch : 13.3%; Total sugars : 0.6%	
Potato		
General	Moisture Content: 171.7–663.4% (db); Corbohydrate: 13.3-30.5%; Total solids: 13.1-36.8%; Protein: 0.70-4.60; Ash: 0.44-1.90%; Crudefibre : 0.17-3.48%	173
Radish		
General	Moisture content : 1860.8% (db); Protein : 0.5%; Carbohydrate : 3.2%; Fat : 0.1%; Minerals : 0.7%; Fibre : 0.6%	173
Sugarbeet	Moisture content : 713% (db); Protein : 1.7%; Carbohydrate: 11.8%; Fat : 0.1%; Minerals : 0.8%; Fibre : 1.1%	34
Sugarcane		
General	Soluble solids : 10-16%; Fibre (dry) : 11-16%; Gur from cane crushed : 10%; Crystal sugar from gur refined: 62.4%; Crystal sugar from cane crused : 9.97%; Khandsari sugar from gur refined : 37.5%; Molasses from cane crushed: 3.5%	3,34
Sugarcane juice		
General	Sugars : 75-92%; Salts : 3.0-4.5%; Protein : 0.5-0.6%; Carboxylic acids : 1.1-3.0%; Amino acids : 0.50-2.5%	34
Sweet potato		
Jawahar 114	Protein : 3.2%; Ash : 0.13%; Oil : 0.3%; Crude fibre : 2.9%; Total carbohydrate : 41.3%; Starch : 39.9%; Free sugar (dry): 0.95%; Phosphourus : 75.3 mg/100 g; Sulphur : 45.9 mg/100 g; Calcium : 562 mg/100 g; Iron : 305.9 ppm	173
Jawahar 145	Protein : 3.5%; Ash : 0.14%; Oil : 0.4%; Crude fibre : 3.1%; Total carbohydrate : 35.5%; Starch : 3.4%; Free soluble sugar (dry) : 1.1%; Phosphorus : 76.6 mg/100 g; Sulphur : 46.1 mg/100g, Calcium : 560 mg/100 g; Iron : 306.5 ppm	
Turnip greens	Crude protein : 5.2%; Crude fat : 0.9%; Crude fibre : 0.6%; Ash : 1.5%	57
Turnip sag	Moisture content : 85% (db); Crude protein : 20.4%; Crude fat : 3.5%; Crude fibre : 6.9%; Ash : 10.8%	57
Water chestnut		
Red	Protein : 10.9%; Ash : 3.6%; Oil : 0.6%; Crude fibre : 0.7%; Total carbohydrate : 69.7%; Starch : 64.3%; Free soluble sugar (dry) : 5.2%: Phosphorus : 45.0 mg/100 g; Sulphur : 60.0 mg/100 g; Calcium : 60.0 mg/100 g; Iron : 145.2 ppm	173
White	Protein : 11.2%; Ash : 2.8%; Oil : 0.8%; Crude fibre : 0.6%; Total carbohydrate : 70.7%; Starch : 67.1%; Free soluble sugar (dry) : 3.3%; Phosphorus : 48.3 mg/100 g; Sulphur : 130.2 mg/100 g; Calcium : 20.0 mg/100 g; Iron : 129.0 ppm	

Table 1.9 : Physico-chemical properties of oils

Oil/Crop variety	Properties	Reference
Aniseed oil		
General	Congealing point : 15° max: Sp. gravity at 20° C : 0.978- 0.992; Solubility at 20° C at 90% alcohol = 1 : 3 vol.; Refractive index at 20° C : 1.553-1.560; Optical rotation : 1-2 to +1°	88
Castor oil		
General	Specific gravity : 0.950-0.974; Saponification value: 81–91; Iodine value : 86-94; Oleic acid : 8.0%; Linolic acid : 4.0%	128
Celery oil		
General	Sp. gravity : 0.850-0.895; Acid value : upto 5; Ester value : 15-40; Refractive index : 1.478-1.486	88
Cinnamon oil		
General	Optical rotation at 20° C : 2.5° to 2° ; Refractive index at 20° C : 1.530-1.540; Solubility in ethanol at 20° C(70% V/V) = 1 : 2 vol.	85
Madagasker	Apparent density at 20° C : 1.032-1.052 g/ml; Total phenols: 70-95% by vol.	
Srilanka	Apparent density at 20° C : 1.034-1.050 g/ml; Total phenols: 75-85% by vol.	
Clove oil		
Bud	Apparent density at 20° C : 1.041-1.054 g/ml; Optical rotation at 20° C : 0-1.5°; Refractive index at 20° C : 1.528–1.538; Total phenols : 85-93% by volume	84
Leaf	Apparent density at 20° C: 1.036-1.048 g/ml: Refractive index at 20° C : 1.531-1.535; Total phenols : 89-90% by volume	
Stem	Apparent densiy at 20° C : 1.048-1.056 g/ml; Refractive index at 20° C : 1.531-1.538; Total phenols : 90-95% by volume	
Conconut oil		
General	Iodine value : 7.5-10.0; Saponification value : 248-265; Unsaponifiable matter : 0.5%; Refractive index : 1.446-1.448; Melting point : 23-26° C	88
Fennel oil		
General	Sp. gravity : 0.9774-0.9767; Optical rotation : 11.42-16.54; Refractive index at 25°C : 1.5355-1.5383; Congealing point: +5.5° to 9.0°; Solubility in vol. 99% alcohol : 1	88
Ginger oil		
General	Sp. gravity at 30° C : 0.8640-0.8758; Optical rotation at 30° C =–30° to - 60°; Refractive index at 20° C : 1.4880-1.4970	79
Groundnut oil		
Spanish bunch	Iodine value : 96.3; Oil stability index = 18 : 1/18 : 2 : 1.3; Nutritional quality index = 18:2/Sat.fatty acid : 1.8; Palmitic, 16:0 = 14.3%; Oleic, 18 : 1 = 44.7%; Linoleic, 18 : 2 = 34.7%	128
Valencia	Iodine value : 98.4; Oil stability index = 18 : 1/18 : 2 = 1.1; Nutritional quality index = 18 : 2/Sat.fatty acid : 2.4; Palmitic > 16 : 0 = 13.3%; Oleic, 18 : 1 = 46.1%; Linoleic > 18 : 2 = 35.9%	
Virginia bunch	Iodine value : 95.4%; Oil stability index, 18 : 1/18 : 2 = 1.5; Nutritional quality index, 18:2/ Sat. fatty acid : 2.2; Palmitic, 16 : 0 = 13.1%; Oleic, 18 : 1 = 47.6%; Linoleic, 18 : 2 = 34.0%	

Table Contd...

Oil/Crop variety	Properties	Reference
Virginia runner	Iodine value : 96.2; Oil stability index, 18 : 1 / 18 : 2 = 1.6; Nutritional quality index, 18:2/Sat. fatty acid : 2.1; Palmitic, 16 : 0 = 12.6%; Oleic, 18 : 1 = 49.7%; Linoleic, 18 : 2 = 31.6%	
Linseed oil		
General	Specific gravity : 0.914-0.930; Refractive index : 1.4756- 1.4802; Acid value : 0.70-2.90%; Iodine value : 153.1-194.3; Saponification value : 192.4-198.3; Palmitic acid : 4.2-15.9%; Oleic acid : 13.0-35.4%; Linoleic acid : 8.1-65.8%	128
Niger seed oil		
General	Refractive index at 40° : 0.5-1.0; Iodine value : 112.8- 129.0; Saponification value : 1.4655-1.4673; Palmitic acid : 6.0- 9.4%; Unsaponifiable matter : 0.2-1.7%; Oleic acid : 13.4-39.3%; Linoleic acid : 45.4-65.8%	128
Nutmeg oil		
General	Apparent viscosity : 0.885-0.915 g/ml; Optical rotation at 20° C : + 8° to 25°; Refractive index at 20° C : 1.4750-1.4880	84
Palm oil		
General	Saturated fatty acid : 53%; Unsaturated fatty acid : 47%	173

Slip melting point 34.5° C	SFI	Fatty acids	% W/W
10° C	37.2	14 : 0	1.1
15° C	33.6	16 : 0	42.1
20° C	26.5	18 : 0	4.4
25° C	14.5	18 : 1	40.6
30° C	8.6	18 : 2	11.3
35° C	4.2		
40° C	0.4		

Oil/Crop variety	Properties	Reference
Safflower oil	Iodine value : 136-146; Saponification value : 186-196; FFA:0.15-1.09%; Butyrometric refractive index at 40°C:62.5-64.5	128
Sesamum oil	Refractive index at 25°C:1.4760-1.4770; Acid value : 1.1- 2.2.; Iodine value: 103.6-112.8; Saponification value:188.6- 191.2; Palmitic acid: 8.4-11.9%; Oleic acid:34.6-47.3%; Linoleic acid:27.9-47.2%; Unsaponifiables:1.4-2.5%	128
Sunflower oil	Specific gravity:0.9109-0.9187; Refractive index at 40°C: 1.4636-1.4681; Acid value:0.7-2.5; Iodine value: 101.4-135.O; Saponification value:1.93-2.0; Oleic acid content:42-57%; Linoleic acid content:33-48%; Unsaponifiable:0.20-1.93%	128

Table 1.10 : Chemical composition of food crops and their by-products (moisture content values based on the whole portion and other values are based on edile portion only) (Source : Reference no. 47)

Product	Edible portion, %	Moisture, % (wb)	Protein, g	Fat, g	Minerals, g	Fibre, g	Carbohydrates, g	Energy, kcal	Calcium, mg	Phosphorus, mg	Iron, mg	Carotene, µg	Thiamine, mg	Riboflavin, mg	Niacin, mg	Vitamin C, mg
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
CEREAL GRAINS AND PRODUCTS																
Bajra (Pearl millet)	84	12.4	9.7	4.2	1.9	1.0	56.7	361	35.3	248.6	4.2	110.9	0.28	0.21	1.9	0
Barley	100	12.5	11.5	1.3	1.2	3.9	69.6	336	26	215	3.0	10	0.47	0.20	5.4	0
Jowar (sorghum)	100	11.9	10.4	1.9	1.6	1.6	72.6	349	25	222	5.8	47	0.37	0.13	3.1	0
Maize (corn)	100	14.9	11.1	3.6	1.5	2.7	66.2	342	10	348	2.0	90	0.42	0.10	1.8	0
Maize, tender	37	67.1	1.7	0.3	0.3	0.7	9.1	125	3.3	44.8	1.2	11.8	0.04	0.06	0.2	2.2
Ragi	100	13.1	7.3	1.3	2.7	3.6	72.0	328	344	283	6.4	42	0.42	0.19	1.1	0
Rice, parboiled, handpounded	100	12.6	8.5	0.6	0.9	..	77.4	349	10	280	2.8	9	0.27	0.12	4.0	0
Rice, parboiled, milled	100	13.3	6.4	0.4	0.7	0.2	79.0	346	9	143	4.0	..	0.21	0.05	3.8	0
Rice, raw, handpounded	100	13.3	7.6	1.0	0.9	0.6	76.7	346	10	190	3.2	2	0.21	0.16	3.9	0
Rice, raw, milled	100	13.7	6.8	0.5	0.6	0.2	78.2	345	10	160	3.1	0	0.06	0.06	1.9	0
Rice bran	..	11.0	13.5	16.2	6.6	4.3	48.4	393	67	1410	35.0	..	2.70	0.48	..	0
Rice flakes	100	12.2	6.6	1.2	2.0	0.7	77.3	346	20	238	20.0	0	0.21	0.05	4.0	0
Rice, puffed	100	14.7	7.5	0.1	3.8	0.3	73.6	325	23	150	6.6	0	0.21	0.01	4.1	0
Sanwa millet	..	11.9	6.2	2.2	4.4	9.8	65.5	307	20	280	2.9	0	..	..	4.2	0
Semolina	100	..	10.4	0.8	..	0.2	74.8	348	16	102	1.6	..	0.12	0.03	1.6	0

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
Wheat Bulgar	100	9.8	8.2	1.6	1.5	1.7	77.2	356	37	298	4.9	..	0.74	0.11	4.8	0
Wheat (whole)	100	12.8	11.8	1.5	1.5	1.2	71.2	346	41	306	4.9	64	0.45	0.17	5.5	0
Wheat flour (whole)	100	12.2	12.1	1.7	2.7	1.9	69.4	341	48	355	11.5	29	0.49	0.17	4.3	0
Wheat flour (refined)	100	13.3	11.0	0.9	0.6	0.3	73.9	348	23	121	2.5	25	0.12	0.07	2.4	0
Wheat germ	100	5.2	29.2	7.4	3.5	1.4	53.3	397	40	846	6.0	..	1.40	0.54	2.9	0
PULSES AND LEGUMES																
Bengal gram (whole)	100	9.8	17.1	5.3	3.0	3.9	60.9	360	202	312	10.2	189	0.30	0.15	2.9	3
Bengal gram dhal	100	9.9	20.8	5.6	2.7	1.2	59.8	372	56	331	9.1	129	0.48	0.18	2.4	1
Bengal gram (roasted)	100	10.7	22.5	5.2	2.5	1.0	58.1	369	58	340	9.5	113	0.20	..	1.3	0
Black gram dhal	100	10.9	24.0	1.4	3.2	0.9	59.6	347	154	385	9.1	38	0.42	0.20	2.0	0
Cow pea	97	13.4	23.4	0.97	3.1	3.7	52.9	323	74.7	401.6	5.7	11.6	0.5	0.19	1.26	0
Field bean, dry	..	9.6	24.9	0.8	3.2	1.4	60.1	347	60	433	2.7	0	0.52	0.16	1.8	0
Green gram (whole)	100	10.4	24.0	1.3	3.5	4.1	56.7	334	124	326	7.3	94	0.47	0.27	2.1	0
Green gram dhal	100	10.1	24.5	1.2	3.5	0.8	59.9	348	75	405	8.5	49	0.47	0.21	2.4	0
Horse gram	100	11.8	22.0	0.5	3.2	5.3	57.2	321	287	311	8.4	71	0.42	0.20	1.5	1
Khesari dhal	100	10.0	28.2	0.6	2.3	2.3	56.6	345	90	317	6.3	120	0.39	0.17	2.9	0
Lentil	100	12.4	25.1	0.7	2.1	0.7	59.0	343	69	293	4.8	270	0.45	0.20	2.6	0
Moth beans	100	10.8	23.6	1.1	3.5	4.5	56.5	330	202	230	9.5	9	0.45	0.09	1.5	2

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
Peas, dry	100	16.0	19.7	1.1	2.2	4.5	56.5	315	75	298	5.1	39	0.47	0.19	3.4	0
Peas, roasted	100	10.1	22.9	1.4	2.4	4.4	58.8	340	81	345	6.4	18	0.47	0.21	3.5	0
Rajmah	..	12.0	22.9	1.3	3.2	..	60.6	346	260	410	5.8	..	..	..	..	..
Redgram dhal	100	13.4	22.3	1.7	3.5	1.5	57.6	335	73	304	5.8	132	0.45	0.19	2.9	0
Soybean	..	8.1	43.2	19.5	4.6	3.7	20.9	432	240	690	11.5	426	0.73	0.39	3.2	..
LEAFY VEGETABLES																
Agathi	..	73.1	8.4	1.4	3.1	2.2	11.8	93	1,130	80	3.9	5,400	0.21	0.09	1.2	169
Amaranth, spined	..	85.0	3.0	0.3	3.6	1.1	7.0	43	800	50	22.9	3,564	0	..	..	33
Amaranth, tender	39	85.7	1.6	0.2	1.1	0.39	2.4	45	154.8	32.4	9.9	2,152.8	0.01	0.11	0.5	38.6
Bamboo, tender shoots	54	88.8	2.1	0.3	0.6	..	3.1	43	10.8	35.1	0.05	0	0.04	0.10	0.11	2.7
Bathua leaves	..	89.6	3.7	0.4	2.6	0.8	2.9	30	150	80	4.2	1,740	0.01	0.14	0.6	35
Beet greens	51	86.4	1.7	0.4	1.1	0.4	3.3	46	193.8	15.3	8.3	2,989.6	0.13	0.29	1.6	35.7
Bengal gram leaves	92	73.4	6.4	1.3	1.9	1.8	12.9	97	312.8	110.4	21.9	899.8	0.08	0.09	0.55	56.1
Bottle gourd leaves	..	87.9	2.3	0.7	1.7	1.3	6.1	39	80	59	..	..	..	..	..	..
Broad bean leaves	..	77.6	5.0	0.3	1.3	3.7	11.5	71	111	14.9	..	..	..	..	..	..
Brussels sprouts	100	85.5	4.7	0.5	1.0	1.2	7.1	52	43	82	1.8	126	0.05	0.16	0.4	72
Cabbage	88	91.9	1.6	0.09	0.9	0.9	4.0	27	34.3	38.7	0.7	105.6	0.05	0.08	0.35	109.1
Carrot leaves	51	76.6	2.6	0.3	1.4	0.97	6.7	77	173.4	56.1	4.5	2,907	0.02	0.19	1.1	40.3
Cauliflower greens	..	80.0	5.9	1.3	3.2	2.0	7.6	66	626	107	40.0	..	..	..	..	..

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
Celery leaves	71	88.0	4.5	0.4	1.5	0.99	1.1	37	163.3	99.4	4.5	2,832.9	0	0.08	0.9	44
Coriander leaves	70	86.3	2.3	0.4	1.6	0.8	4.4	44	128.8	49.7	12.9	4,842.6	0.04	0.04	0.6	94.5
Cowpea leaves	..	89.0	3.4	0.7	1.6	1.2	4.1	38	290	58	20.1	6,072	0.05	0.18	0.6	4
Curry leaves	83	63.8	5.1	0.83	3.3	5.3	15.5	108	688.9	47.3	5.8	6,274.8	0.07	0.17	1.9	3.3
Drumstick leaves	75	75.9	5.0	1.3	1.7	0.7	9.4	92	330	52.5	5.3	5,085	0.05	0.04	0.6	165
Fenugreek leaves	59	86.1	2.6	0.5	0.9	0.6	3.5	49	233.1	30.1	9.7	1,380.1	0.02	0.18	0.47	30.7
Khesari leaves	..	84.2	6.1	1.0	1.1	2.1	5.5	55	160	100	7.3	3,000	0.01	0.03	..	41
Knol-khol greens	73	86.7	2.6	0.29	0.9	1.3	4.7	43	540.2	36.5	9.7	3,026.6	0.18	..	2.2	114.6
Koila karha sag	..	87.2	3.0	0.4	2.8	1.4	5.2	36	330	21	..	..	..	..	..	..
Lettuce	66	93.4	1.4	0.19	0.8	0.3	1.7	21	33	18.5	1.6	653.4	0.06	0.09	0.33	6.6
Lettuce tree leaves, mature	..	81.7	5.1	0.4	2.6	..	10.2	65	320	80	2.6	..	..	..	..	..
Lettuce tree leaves, tender	..	90.2	3.6	0.2	2.2	0.6	3.2	29	170	60	3.6	888	0.03	0.11	0.2	10
Mint	45	84.9	2.2	0.27	0.9	0.9	2.6	48	90	27.9	7.0	729	0.02	0.12	0.45	12.2
Mustard leaves	..	89.8	4.0	0.6	1.6	0.8	3.2	34	155	26	16.3	2,622	0.03	..	..	33
Neem leaves, mature	..	59.4	7.1	1.0	3.4	6.2	22.9	129	510	80	17.1	1,998	0.04	0	1.4	218
Neem leaves, tender	100	59.4	11.6	3.0	2.6	2.2	21.2	158	130	190	25.3	2,760	0.06	0	1.5	104
Parsley	82	74.6	4.8	0.82	2.6	1.5	11.1	87	319.8	143.5	14.7	1,574.4	0.03	0.15	0.4	230.4

Table Contd....

1	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
Parwar sag	..	80.5	5.4	1.1	3.0	4.2	5.8	55	531	73	..	..	..	..	..	..
Potato leaves	..	88.0	4.4	0.9	1.8	1.3	3.6	40	120	50	..	..	..	..	..	..
Pumpkin leaves	..	81.9	4.6	0.8	2.7	2.1	7.9	57	392	112	..	..	..	..	..	..
Radish leaves	100	90.8	3.8	0.4	1.6	1.0	2.4	28	265	59	3.6	5,295	0.18	0.47	0.8	81
Rape leaves	..	84.9	5.1	0.4	2.5	1.2	5.9	48	370	110	12.5	1380	0.01	0.03	0.9	65
Rape leaves (dried)	..	7.4	27.0	2.9	15.3	6.7	40.7	297	3095	500	..	..	..	..	..	..
Sonchal sag	100	86.2	4.3	0.6	2.1	1.2	5.6	45	300	60	19.5	2490	..	..	0.2	79
Spinach	87	92.1	1.7	0.61	1.5	0.5	2.5	26	63.5	18.3	9.5	4854.6	0.026	0.23	0.4	24.4
Soya leaves	..	79.5	6.0	0.5	3.2	..	10.8	72	180	190	8.0	..	..	0.16	..	..
Sweet potato greens	100	80.7	4.2	0.8	2.2	2.4	9.7	63	360	60	10.0	750	0.07	0.24	1.7	27
Table radish leaves	49	89.1	1.9	0.3	0.8	0.3	2.1	38	151.9	29.4	8.8	2813.6	0.09	0.17	2.7	51.9
Tamarind leaves, tender	100	70.5	5.8	2.1	1.5	1.9	18.2	115	101	140	5.2	250	0.24	0.17	4.1	3
Tamarind leaves, tender, dried	..	8.9	8.6	3.0	8.5	10.1	60.9	305	1485	124	..	..	..	..	..	..
Turnip greens	51	81.9	2.0	0.77	1.1	0.51	4.8	34.2	362.1	30.6	14.5	4791.9	0.16	0.29	2.8	91.8
ROOTS AND TUBERS																
Banana rhizome	35	85.1	0.14	0.07	0.49	0.39	4.1	51	8.8	3.5	0.39	5.6	0	0.01	0.07	0.35
Beet root	85	87.7	1.4	0.09	0.7	0.8	7.5	43	15.6	46.8	0.85	0	0.03	0.08	0.34	8.5
Carrot	95	86.0	0.86	0.19	1.04	1.14	10.1	48	76	503.5	2.1	1795.5	0.038	0.019	0.57	2.85

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
Lotus root	..	85.9	1.7	0.1	0.2	0.8	11.3	53	21	74	0.4	..	0.10	..	..	22
Mango ginger	87	85.0	0.96	0.61	1.22	1.13	9.14	53	21.8	78.3	2.3	17.4	0.08	0.026	0	0.87
Onion, big	95	86.6	1.1	0.095	0.38	0.57	10.5	50	44.6	47.5	0.67	0	0.076	0.009	0.38	10.5
Onion, small	..	84.3	1.8	0.1	0.6	0.6	12.6	59	40	60	1.2	15	0.08	0.02	0.5	2
Potato	85	74.7	1.4	0.09	0.5	0.3	19.2	97	8.5	34	0.6	20	0.09	0.009	1.0	14.5
Radish, pink	98	90.8	0.59	0.29	0.88	0.59	6.7	32	49	19.6	0.49	2.9	0.059	0.019	0.39	16.7
Radish, rat-tailed	..	92.3	1.3	0.3	0.7	1.1	4.3	25	78	24	..	..	..	..	..	..
Radish, table	100	94.9	0.5	0.1	0.7	0.6	3.2	16	20	20	1.0	4	0.02	0.03	1.4	21
Radish, white	99	94.4	0.69	0.099	0.59	0.79	3.57	17	34.7	21.8	0.396	2.97	0.059	0.019	0.495	14.9
Sweet potato	97	68.5	1.16	0.29	0.97	0.78	27.4	120	44.6	48.5	0.78	5.8	0.078	0.039	0.68	23.3
Tapioca	..	59.4	0.7	0.2	1.0	0.6	38.1	157	50	40	0.9	..	0.05	0.10	0.3	25
Tapioca chips, dried	100	12.0	1.3	0.3	2.0	1.8	82.6	338	91	70	3.6	0	0.23	0.10	1.4	0
Turnip	65	91.6	0.33	0.13	0.4	0.6	4	29	19.5	26	0.3	0	0.03	0.03	0.33	27.9
Yam, elephant	..	78.7	1.2	0.1	0.8	0.8	18.4	79	50	34	0.6	260	0.06	0.07	0.7	0
Yam, ordinary	92	69.9	1.3	0.09	1.5	0.92	23.9	111	32.2	18.4	1.2	71.8	0.06	..	0.6	..
Yam, wild	89	70.4	2.2	0.27	1.2	0.89	21.7	110	17.8	65.9	0.89	502.9	0.17	0.42	1.07	0.89

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
Water lily, red	..	49.1	4.1	0.3	1.6	1.5	43.4	193	65	217	..	..	..	..	..	..
Water lily, white	..	62.5	3.1	0.3	1.3	1.1	31.7	142	76	220	..	..	..	..	..	..
OTHER VEGETABLES																
Amaranth stem	..	92.5	0.9	0.1	1.8	1.2	3.5	19	260	30	1.8	255	0.01	0.18	0	10
Ash gourd	67	96.5	0.3	0.07	0.2	0.5	1.3	10	20.1	13.4	0.5	0	0.04	0.007	0.3	0.67
Beans, scarlet runner	59	58.3	4.4	0.59	0.9	1.1	17.6	158	29.5	94.4	1.5	20.1	0.2	0.11	0	15.9
Bitter gourd	97	92.4	1.55	0.19	0.6	0.6	4.1	25	19.4	67.9	1.7	122.2	0.067	0.087	0.49	85.4
Bitter gourd, small	93	83.2	1.9	0.9	1.3	1.6	9.9	60	21.4	35.3	1.9	177.2	0.065	0.056	0.37	89.3
Bottle gourd	86	96.1	0.17	0.09	0.4	0.5	2.2	12	17.2	8.6	0.6	0	0.026	0.009	1.7	0
Brinjal	91	92.7	1.3	0.27	0.27	1.18	3.6	24	16.4	42.8	0.8	67.3	0.036	0.10	0.8	10.9
Broad beans	88	85.4	3.96	0.09	0.7	1.8	6.3	48	44.0	56.3	1.2	7.9	0.07	..	0.7	10.6
Cauliflower	70	90.8	1.8	0.3	0.7	0.8	2.8	30	23.1	39.9	1.1	21.0	0.03	0.07	0.7	39.2
Celery stalks	..	93.5	0.8	0.1	0.9	1.2	3.5	18	30	38	4.8	520	0.12	0.05	0.3	6
Cluster beans	..	81.0	3.2	0.4	1.4	3.2	10.8	16	130	57	4.5	198	0.09	0.03	0.6	49
Cowpea pods	..	85.3	3.5	0.2	0.9	2.0	8.1	48	72	59	2.5	564	0.07	0.09	0.9	14
Cucumber	83	96.3	0.3	0.08	0.2	0.3	2.1	13	8.3	20.8	1.2	0	0.02	0	0.17	5.8
Drumstick	83	86.9	2.1	0.083	1.7	3.9	3.1	26	24.9	91.3	4.4	91.3	0.04	0.06	0.17	99.6
Drumstick flowers	..	85.9	3.6	0.8	1.3	1.3	7.1	50	51	90	..	..	..	..	..	..

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
Field beans, tender	93	86.1	3.5	0.65	0.84	1.7	6.2	48	195.3	63.2	1.6	173.9	0.09	0.056	0.65	8.4
Figs, red	..	79.4	1.2	0.6	1.6	6.4	10.8	53	187	39	..	..	..	..	..	..
French beans	94	91.4	1.6	0.09	0.47	1.7	4.2	26	47	26.3	1.6	124.1	0.075	0.056	0.28	22.6
Giant chillies (capsicum)	97	92.4	1.26	0.29	0.68	0.97	4.2	24	9.7	29.1	1.16	414.2	0.53	0.049	0.097	132.9
Jack, tender	..	84.0	2.6	0.3	0.9	2.8	9.4	51	30	40	1.7	0	0.05	0.04	0.2	14
Kandan kathiri	..	75.5	3.1	0.8	1.6	14.2	4.8	39	100	90	1.2	..	..	..	..	..
Karonda, fresh	98	91.0	1.08	2.8	0.59	1.47	2.8	42	20.6	27.4	..	..	..	..	..	..
Karonda, dry	..	18.2	2.3	9.6	2.8	..	67.1	364	160	60	39.1	..	..	..	..	..
Knol-khol	74	92.7	0.8	0.1	0.5	1.1	2.8	21	14.8	25.9	0.3	15.5	0.04	0.07	0.4	62.9
Ladies fingers	84	89.6	1.6	0.17	0.6	1.0	5.4	35	55.4	47.0	1.3	43.7	0.06	0.08	0.5	10.9
Lotus stem, dry	100	9.5	4.1	1.3	8.7	25.0	51.4	234	405	128	60.6	0	0.82	1.21	1.9	3
Mango, green	72	87.5	0.5	0.07	0.3	0.9	7.3	44	7.2	13.7	3.9	64.8	0.03	0.007	0.1	2.2
Onion stalks	100	87.6	0.9	0.2	0.8	1.6	8.9	41	50	50	7.5	595	0	0.03	0.3	17
Papaya, green	..	92.0	0.7	0.2	0.5	0.9	5.7	27	28	40	0.9	0	0.01	0.01	0.1	12
Parwar	95	92.0	1.9	0.29	0.48	2.9	2.1	20	28.5	38	1.6	145.4	0.048	0.057	0.48	27.6
Peas	53	72.1	3.8	0.05	0.4	2.1	8.4	93	10.6	73.7	0.8	43.9	0.13	0.005	0.4	4.8
Pink beans	94	86.8	2.9	0.38	0.56	1.97	6.6	44	50.8	65.8	1.4	425.8	0.056	0.019	0.56	11.3

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
Plantain flower	43	89.9	0.7	0.3	0.6	0.6	2.2	34	13.8	18.1	0.7	11.6	0.02	0.009	0.2	6.9
Plantain, green	58	83.2	0.8	0.1	0.3	0.4	8.1	64	5.8	16.8	0.3	17.4	0.03	0.01	0.2	13.9
Plantain stem	..	88.3	0.5	0.1	0.6	0.8	9.7	42	10	10	1.1	0	0.02	0.01	0.2	7
Pumpkin	79	92.6	1.1	0.08	0.5	0.6	3.6	25	7.9	23.7	0.6	39.5	0.05	0.03	0.4	1.6
Pumkin flowers	..	89.1	2.2	0.8	1.4	0.7	5.8	39	120	60	..	..	..	..	..	..
Rape plant, stem	..	91.4	3.1	0.1	1.4	..	4.0	29	100	100	1.2	..	..	..	..	..
Redgram, tender	72	65.1	7.1	0.7	0.7	4.5	12.2	116	41.0	118.1	0.8	337.7	0.23	0.24	2.2	18
Ridge gourd	82	95.2	0.4	0.08	0.25	0.4	2.8	17	14.8	21.3	0.4	27.1	..	0.008	0.16	4.1
Sannhemp flowers	..	78.9	4.8	0.6	1.4	3.9	10.4	66	200	100	..	..	..	..	..	..
Snake gourd	98	94.6	0.49	0.29	0.49	0.78	3.23	18	25.48	19.6	0.29	94.1	0.039	0.059	0.29	0
Spinach stalks	..	93.4	0.9	0.1	1.8	..	3.8	20	90	20	1.6	..	..	..	..	3
Spinach beans	98	87.2	2.65	0.19	0.59	1.47	7.6	44	58.8	39.2	1.96	23.52	0.078	0.078	0.49	12
Tinda, tender	99	93.5	1.39	0.19	0.49	0.99	3.37	21	24.8	23.8	0.89	12.9	0.039	0.079	0.29	17.82
Tomato, green	98	93.1	1.86	0.098	0.59	0.69	3.53	23	19.6	35.3	1.76	188.2	0.069	0.0098	0.39	30.38
Vegetable marrow	94	94.8	0.5	0.1	0.3	0.8	3.5	17	10	30	0.6	..	0.02	0	0.4	18
Water chestnut, fresh	38	70.0	1.8	0.1	0.4	0.2	8.9	115	7.6	57	0.3	4.6	0.02	0.03	0.2	3.4
Water chestnut, dry	..	13.8	13.4	0.8	3.1	..	68.9	336	70	440	2.4	..	..	..	..	..

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
Waterlily flowers	..	90.8	1.6	0.6	0.7	0.9	5.4	33	29	18	..	..	..	..	..	..
NUTS AND OILSEEDS																
Almond	..	5.2	20.8	58.9	2.9	1.7	10.5	655	230	490	4.5	0	0.24	0.57	4.4	0
Cashewnut	..	5.9	21.2	46.9	2.4	1.3	22.3	596	50	450	5.0	60	0.63	0.19	1.2	0
Chilgoza	..	4.0	13.9	49.3	2.8	1.0	29.0	615	91	494	3.6	..	0.32	0.30	3.6	0
Coconut, dry	..	4.3	6.8	62.3	1.6	6.6	18.4	662	400	210	2.7	0	0.08	0.01	3.0	7
Coconut, fresh	100	36.3	4.5	41.6	1.0	3.6	13.0	444	10	240	1.7	0	0.05	0.10	0.8	1
Gingelly seeds	100	5.3	18.3	43.3	5.2	2.9	25.0	563	1450	570	10.5	60	1.01	0.34	4.4	0
Groundnut	73	3.0	18.5	29.3	1.8	2.3	19.1	567	65.7	255.5	2.0	27.0	0.66	0.09	14.5	0
Groundnut, roasted	69	1.7	18.1	27.5	1.7	2.1	18.4	570	53.1	255.3	2.1	0	0.27	0.09	15.2	0
Jungli badam	10	35.6	1.1	3.6	0.2	..	..	..	3.3	4.2	0.2	0	0.006	0.008	0.1	0.5
Linseed seeds	99	6.5	20.1	36.7	2.38	4.75	28.6	530	168.3	366.3	2.67	29.7	0.228	0.069	0.99	0
Mustard seeds	..	8.5	20.0	39.7	4.2	1.8	23.8	541	490	700	17.9	162	0.65	0.26	4.0	0
Niger seeds	..	4.2	23.9	39.0	4.9	10.9	17.1	515	300	224	56.6	..	0.07	0.97	8.4	0
Pistachio nut	..	5.6	19.8	53.5	2.8	2.1	16.2	626	140	430	7.7	144	0.67	0.28	2.3	..
Safflower seeds	..	5.5	13.5	25.6	2.6	34.9	17.9	356	236	823	..	..	..	..	..	..
Sunflower seeds	52	5.5	10.3	27.1	1.9	0.52	9.3	620	145.6	348.4	2.6	0	0.45	0.01	2.3	0.52
Walnut	45	4.5	7.0	29.0	0.81	1.2	4.9	687	45	171	2.2	2.7	0.20	0.18	0.45	0

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
CONDIMENTS AND SPICES																
Arisithippili	..	12.5	13.2	4.7	6.0	5.2	58.4	329	460	325	13.5	..	..	..	..	..
Asafoetida	..	16.0	4.0	1.1	7.0	4.1	67.8	297	690	50	22.2	4	0	0.04	0.3	0
Cardamom	..	20.0	10.2	2.2	5.4	20.1	42.1	229	130	160	5.0	0	0.22	0.17	0.8	0
Chillies, dry	..	10.0	15.9	6.2	6.1	30.2	31.6	246	160	370	2.3	345	0.93	0.43	9.5	50
Chillies, green	90	85.7	2.6	0.5	0.9	6.1	2.7	29	27	72	1.1	157.5	0.17	0.35	0.8	99.9
Cloves, dry	100	25.2	5.2	8.9	5.2	9.5	46.0	286	740	100	4.9	253	0.08	0.13	0	0
Cloves, green	..	65.5	2.3	5.9	2.2	..	24.1	159	310	40	2.1	72	..	..	..	..
Coriander	..	11.2	14.1	16.1	4.4	32.6	21.6	288	630	393	17.9	942	0.22	0.35	1.1	0
Cumin seeds	..	11.9	18.7	15.0	5.8	12.0	36.6	356	1080	511	31.0	522	0.55	0.36	2.6	3
Fenugreek seeds	..	13.7	26.2	5.8	3.0	7.2	44.1	333	160	370	14.1	96	0.34	0.29	1.1	0
Garlic, dry	85	62.0	5.4	0.09	0.9	0.7	25.3	145	25.5	263.5	1.1	0	0.05	0.20	0.3	11.1
Ginger, fresh	..	80.9	2.3	0.9	1.2	2.4	12.3	67	20	60	2.6	40	0.06	0.03	0.6	6
Lime peel	..	66.5	1.8	0.5	1.8	..	29.4	129	710	60	2.7	..	..	..	..	..
Mace	..	15.9	6.5	24.4	1.6	3.8	47.8	437	180	100	12.6	3027	0.25	0.42	1.4	0
Nutmeg	..	14.3	7.5	36.4	1.7	11.6	28.5	472	120	240	4.6	0	0.33	0.01	1.4	0
Nutmeg rind	..	86.8	1.0	0.4	0.6	..	11.2	52	40	10	2.0	4	..	..	..	..
Pepper, dry	95	13.2	10.9	6.5	4.2	14.2	46.7	304	437	188.1	15.9	1026	0.086	0.13	1.3	..
Pepper, green	81	70.6	3.9	2.2	1.5	5.2	11.1	98	218.7	56.7	1.9	437.4	0.04	0.03	0.16	0.81
Tamarind pulp	..	20.9	3.1	0.1	2.9	5.6	67.4	283	170	110	10.9	60	..	0.07	0.7	3

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
Turmeric	100	13.1	6.3	5.1	3.5	2.6	69.4	349	150	282	14.8	30	0.03	0	2.3	0
FRUITS																
Amla	89	81.8	0.4	0.09	0.4	3.0	12.2	58	44.5	17.8	1.1	8.0	0.027	0.009	0.18	534
Apple	90	84.6	0.18	0.45	0.27	0.9	12.1	59	9	12.6	0.9	0	..	..	0	0.9
Apricots, fresh	86	85.3	0.86	0.26	0.6	0.95	9.98	53	17.2	21.5	1.9	1857.6	0.03	0.11	0.5	5.2
Apricots, dried	93	19.4	1.5	0.65	2.6	1.95	68.3	306	102.3	65.1	4.3	53.9	0.20	..	2.1	1.9
Avocado pear	..	73.6	1.7	22.8	1.1	..	0.8	215	10	80	0.7	..	..	..	..	..
Bael fruit	64	61.5	1.2	0.2	1.1	1.9	20.4	137	54.4	32	0.4	35.2	0.08	0.02	0.7	5.1
Bamboo fruit	..	56.3	3.9	0.1	1.6	3.9	34.2	153	10	110	1.5	11	0.09	0.09	..	1
Banana, ripe	71	70.1	0.9	0.2	0.6	0.3	19.3	116	12.1	25.6	0.6	55.4	0.04	0.06	0.4	4.9
Banyan tree figs	..	74.1	1.7	2.0	1.9	8.5	11.8	72	364	43	..	..	..	..	..	..
Blackberry	100	87.2	1.3	0.5	0.5	3.8	6.7	37	30	20	4.3	7	..	..	2.0	9
Bread fruit	..	79.5	1.5	0.2	0.9	2.1	15.8	71	40	30	0.5	9	0.04	0.07	..	21
Cape gooseberry	87	82.9	1.6	0.17	0.7	2.8	9.7	53	8.7	58.3	1.7	1242.4	0.04	0.017	0.26	42.6
Cashew fruit	77	86.3	0.15	0.08	0.15	0.69	9.5	51	7.7	7.7	0.15	17.7	0.015	0.039	0.31	138.6
Cherries, red	88	83.4	0.97	0.4	0.7	0.35	12.1	64	21.1	22	1.1	0	0.07	0.07	0.26	6.2
Currants, black	98	18.4	2.6	0.49	2.16	0.98	73.7	316	127.4	107.8	8.3	20.6	0.029	0.137	0.39	0.98
Dates, dried	86	15.3	2.15	0.3	1.8	3.4	65.2	317	103.2	43	6.3	22.4	0.009	0.017	0.8	2.6
Dates, fresh	..	59.2	1.2	0.4	1.7	3.7	33.8	144	22	38	..	..	..	..	..	..

Table Contd...

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
Figs	99	88.1	1.29	0.19	0.59	2.18	7.52	37	79.2	29.7	0.99	160.4	0.059	0.049	0.59	4.95
Grapes, blue variety	95	82.2	0.57	0.38	0.86	2.7	12.4	58	19	21.9	0.48	2.9	0.038	0.029	0.19	0.95
Grapes, pale green variety	..	79.2	0.5	0.3	0.6	2.9	16.5	71	20	30	0.5	0	..	..	0	1
Grapefruit (Marsh's seedless)	..	88.5	1.0	0.1	0.4	..	10.0	45	30	30	0.2	..	0.12	0.02	0.3	..
Grapefruit (Triumph)	..	92.0	0.7	0.1	0.2	..	7.0	32	20	20	0.2	..	0.12	0.02	0.3	31
Guava, country	100	81.7	0.9	0.3	0.7	5.2	11.2	51	10	28	1.4	0	0.03	0.03	0.4	212
Guava, hill	..	85.3	0.1	0.2	0.6	4.8	9.0	38	50	20	1.2	0	0.02	0.02	0.3	15
Jack fruit	30	76.2	0.6	0.03	0.3	0.3	5.9	88	6	12.3	0.2	52.5	0.009	0.04	0.12	2.1
Jambu fruit	75	83.7	0.5	0.2	0.3	0.7	10.5	62	11.3	11.3	0.9	36	0.02	0.008	0.15	13.5
Kusum fruits	..	86.2	1.5	0.8	1.0	0.6	9.9	53	15	42	..	..	..	..	..	..
Lemon	..	85.0	1.0	0.9	0.3	1.7	11.1	57	70	10	2.3	0	0.02	0.01	0.1	39
Lichi	68	84.1	0.7	0.1	0.3	0.3	9.2	61	6.8	23.8	0.5	0	0.01	0.04	0.3	21.1
Lichies, bastard	..	83.9	1.4	0.3	0.8	0.5	13.1	61	15	35	..	..	..	..	..	..
Lime	..	84.6	1.5	1.0	0.7	1.3	10.9	59	90	20	0.3	15	0.02	0.03	0.1	63
Lime, sweet, malta	67	90.3	0.5	0.1	0.3	0.4	5.2	36	20.1	13.4	0.7	0	..	..	0	36.2
Lime, sweet, musambi	71	88.4	0.6	0.2	0.5	0.4	6.6	43	28.4	21.3	0.5	0	..	..	0	35.5
Loquat	76	88.2	0.5	0.2	0.4	0.6	7.3	43	22.8	15.2	0.99	424.8	..	..	0	0

Table Contd...

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
Mahua, ripe	..	73.6	1.4	1.6	0.7	..	22.7	111	45	22	1.1	307	..	..	..	40
Mango, ripe	74	81.0	0.4	0.3	0.3	0.5	12.5	74	10.4	11.8	0.96	2029.8	0.06	0.07	0.7	11.8
Melon, musk	78	95.2	0.2	0.16	0.3	0.3	2.7	17	24.9	10.9	1.1	131.8	0.09	0.06	0.2	20.3
Melon, water	78	95.8	0.16	0.16	0.2	0.16	2.6	16	8.6	9.4	6.2	0	0.016	0.03	0.08	0.8
Mulberry	100	86.5	1.1	0.4	0.6	1.1	10.3	49	70	30	2.3	57	0.04	0.13	0.5	12
Neem fruit	..	81.9	1.3	1.0	0.7	..	15.1	75	25	41	..	..	..	..	..	..
Orange	67	87.6	0.5	0.1	0.2	0.2	7.3	48	17.4	13.4	0.21	739.7	..	..	..	20.1
Orange juice	..	97.7	0.2	0.1	0.1	..	1.9	9	5	9	0.7	15	0.06	0.02	0.4	64
Papaya, ripe	75	90.8	0.5	0.08	0.4	0.6	5.4	32	12.8	9.8	0.4	499.5	0.03	0.19	0.15	42.8
Passion fruit	..	76.3	0.9	0.1	0.7	9.6	12.4	54	10	60	2.0	54	0.07	0.14	1.6	25
Passion fruit juice	100	89.0	1.2	0.2	0.7	1.2	7.7	37	10	30	0.7	1968	0.01	0.02	0	13
Peaches	88	86.0	1.1	0.26	0.7	1.1	9.2	50	13.2	36.1	2.1	0	0.018	0.026	0.44	5.3
Pears	85	86.0	0.5	0.17	0.26	0.9	10.1	52	6.8	12.8	0.4	23.8	0.05	0.026	0.17	0
Phalsa	69	80.8	0.9	0.6	0.76	0.8	10.1	72	89.0	26.9	2.1	289.1	..	..	0.2	15.2
Pine apple	60	87.8	0.24	0.06	0.24	0.3	6.5	46	12.0	5.4	0.72	10.8	0.12	0.07	0.06	23.4
Pipal tree figs	..	62.4	2.5	1.7	2.3	9.9	21.2	110	289	89	..	..	..	..	..	..
Plum	90	86.9	0.6	0.45	0.36	0.36	9.99	52	9	10.8	0.5	149.4	0.036	0.09	0.27	4.5

Table Contd...

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
Pomegranate	68	78.0	1.09	0.07	0.5	3.5	9.9	65	6.8	47.6	0.2	0	0.04	0.07	0.2	10.9
Prunes	..	85.3	0.5	0.3	0.6	0.5	12.8	56	10	18	..	..	..	..	..	..
Raisins	100	20.2	1.8	0.3	2.0	1.1	74.6	308	87	80	7.7	2.4	0.07	0.19	0.7	1
Raspberry	..	84.8	1.0	0.6	0.9	1.0	11.7	56	40	110	2.3	1248	..	..	0.8	30
Rose apple	100	89.1	0.7	0.2	0.3	1.2	8.5	39	10	30	0.5	141	0.01	0.05	0.4	3
Sapota	83	73.7	0.6	0.9	0.4	2.2	17.8	98	23.2	22.4	1.7	80.5	0.017	0.02	0.17	4.98
Seethaphal	45	70.5	0.7	0.2	0.41	1.4	10.6	104	7.7	21.2	0.7	0	0.03	0.08	0.6	16.7
Strawberry	96	87.8	0.67	0.19	0.38	1.06	9.4	44	28.8	28.8	1.7	17.3	0.029	0.19	0.19	49.9
Tomato, ripe	100	94.0	0.9	0.2	0.5	0.8	3.6	20	48	20	0.4	351	0.12	0.06	0.4	27
MISCELLANEOUS FOODSTUFFS																
Amaranth seeds	100	10.0	14.7	1.9	3.1	9.6	60.7	319	510	397	11.0	..	0.07	0.21	0.5	1
Arecanut	..	31.3	4.9	4.4	1.0	11.2	47.2	249	50	130	1.5	3.0	..	..	..	..
Arrow root flour	..	16.5	0.2	0.1	0.1	..	83.1	334	10	20	1.0	..	..	..	..	..
Avocado pear (nut)	..	63.7	2.5	0.7	1.1	..	32.0	144	20	80	1.2	..	..	..	..	..
Betel leaves	..	85.4	3.1	0.8	2.3	2.3	6.1	44	230	40	7.0	5760	0.07	0.03	0.7	5
Bread, brown	100	39.0	8.8	1.4	..	1.2	49.0	244	18	..	2.2	..	0.21	..	2.5	..
Bread, white	100	39.0	7.8	0.7	..	0.2	51.9	245	11	..	1.1	..	0.07	..	0.7	..
Cane sugar	100	0.4	0.1	0	0.1	0	99.4	398	12	1	..	..	..	..	..	..

Table Contd...

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
Cholai or Seel	..	11.5	13.6	5.5	3.1	5.6	60.7	347	160	550	4.5	..	..	..	3.7	..
Coconut, tender	..	90.8	0.9	1.4	0.6	..	6.3	41	10	30	0.9	..	..	..	..	2
Coconut milk	100	42.8	3.4	41.0	0.9	0	11.9	430	15	140	1.6	0	0.08	0.04	0.6	3
Coconut water	100	93.8	1.4	0.1	0.3	0	4.4	24	24	10	0.1	0	0.01	0	0.1	2
Coconut meal, deoiled	100	8.7	23.8	2.8	7.0	9.8	47.9	312	112	646	69.4	0	0.13	0.57	6.0	5
Groundnut cake	..	7.2	40.9	7.4	2.5	3.2	38.8	386	213	548	..	..	..	..	..	..
Honey	..	20.6	0.3	0	0.2	..	79.5	319	5	16	0.9	0	0	0.04	0.2	4
Jack fruit seeds	..	64.5	6.6	0.4	1.2	1.5	25.8	133	50	97	1.5	10	0.25	0.11	0.3	11
Jaggery (cane)	..	3.9	0.4	0.1	0.6	..	95	383	80	40	11.4	168	0.02	0.04	0.5	0
Jaggery (coconut palm)	..	10.3	1.0	0.2	5.0	..	83.5	340	1638	62	..	..	..	..	..	..
Jaggery (date palm)	..	9.6	1.5	0.3	2.6	..	86.1	353	363	62	..	..	..	..	..	..
Jaggery (fan palm)	..	8.6	1.0	0.1	1.8	..	98.5	359	225	44	..	..	..	..	..	..
Jaggery (sago palm)	..	9.2	2.3	0.1	3.7	..	84.7	349	1252	372	..	..	..	..	..	..
Lotus seed, dry	..	10.0	17.2	2.4	3.8	2.6	64.0	346	36	294	2.3	..	..	..	..	..
Lotus seed, green and mature	..	84.6	3.9	0.7	1.1	0.9	8.8	57	49	151	..	..	..	..	..	..
Mahua flowers	89	18.6	3.9	0.5	2.4	1.5	64.1	311	124.6	124.6	13.4	20.5	0.027	0.78	4.6	6.2
Makhana	..	12.8	9.7	0.1	0.5	..	76.9	347	20	90	1.4	..	..	..	..	..
Mango seed kernel	54	55.0	1.4	2.3	0.8	0.5	19.4	192	21.6	59.4	0.4	1.8	0.11	0.10	0	4.9

Table Contd...

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
Mango powder	..	6.8	2.8	7.8	4.9	13.7	64.0	337	180	160	45.2	0	..	..	0.7	41
Marking nut (kernel)	..	3.8	26.4	36.4	3.6	1.4	28.4	587	295	836	6.1	..	0.38	0.15	2.7	..
Mushroom	88	88.5	2.7	0.7	1.2	0.35	3.8	43	5.3	96.8	1.3	0	0.12	0.14	2.1	10.6
Poppy seeds	..	4.3	21.7	19.3	9.9	8.0	36.8	408	1584	432	..	..	..	..	..	..
Pumpkin seeds	70	8.0	17.0	33.0	3.3	0.14	10.9	584	35	581	3.9	26.6	0.23	0.11	2.2	0.7
Red palm oil	100	..	..	100	..	..	..	900	..	..	..	..	..	..	..	..
Sago	..	12.2	0.2	0.2	0.3	..	87.1	351	10	10	1.3	..	0.01	..	0.2	..
Sea weeds, fresh	100	91.0	0.8	0.2	4.0	0.3	3.7	20	134	10	7.0	560	0.05	..	1.7	..
Sea weeds, dry	100	9.5	10.8	0.8	22.7	5.0	51.2	255	1543	114	..	94	0.04	..	0	1
Sugar cane juice	..	90.2	0.1	0.2	0.4	..	9.1	39	10	10	1.1	6	..	0.04	..	..
Tamarind seed kernel, roasted	..	9.9	16.1	7.3	1.6	1.0	64.1	387	121	237	..	..	..	..	..	..
Toddy fermented	..	97.6	0.1	0.3	0.2	..	1.8	38	..	..	..	0	0.01	0.01	0.2	..
Toddy sweet	..	84.7	0.1	0.3	0.7	..	14.3	59	150	10	0.3	..	..	0.04	..	..
Water lily seeds	..	10.0	8.3	1.0	0.9	4.2	75.6	345	20	110	..	..	..	..	..	..
Water melon seeds (kernel)	..	4.3	34.1	52.6	3.7	0.3	4.5	623	400	937	7.4	..	0.13	0.20	1.3	..
Yeast, dried (Brewer's)	..	13.6	39.5	0.6	7.0	0.2	39.1	320	440	1490	43.7	66	6.0	4.0	40.0	0
Yeast, dried (food)	..	7.8	35.7	1.8	8.4	..	46.3	344	160	2090	21.5	..	3.20	..	27.0	0

CHAPTER-II

SPATIAL DIMENSIONS, SIZE AND SPHERICITY

Engineering properties of biomaterials play an important role in designing the equipments which are used for post harvest operations and storage. Shape and size are important parameters which govern design of winnowers, cleaners and graders. In conveying of solid materials by air or water, estimate of the frontal area and related diameters are needed for determination of terminal velocity, drag coefficient and Reynold's number. Further, they are also important in the analysis of problems of heat and mass transfer, pneumatic and hydraulic handling and separation, electrostatic separation of seeds and grains.

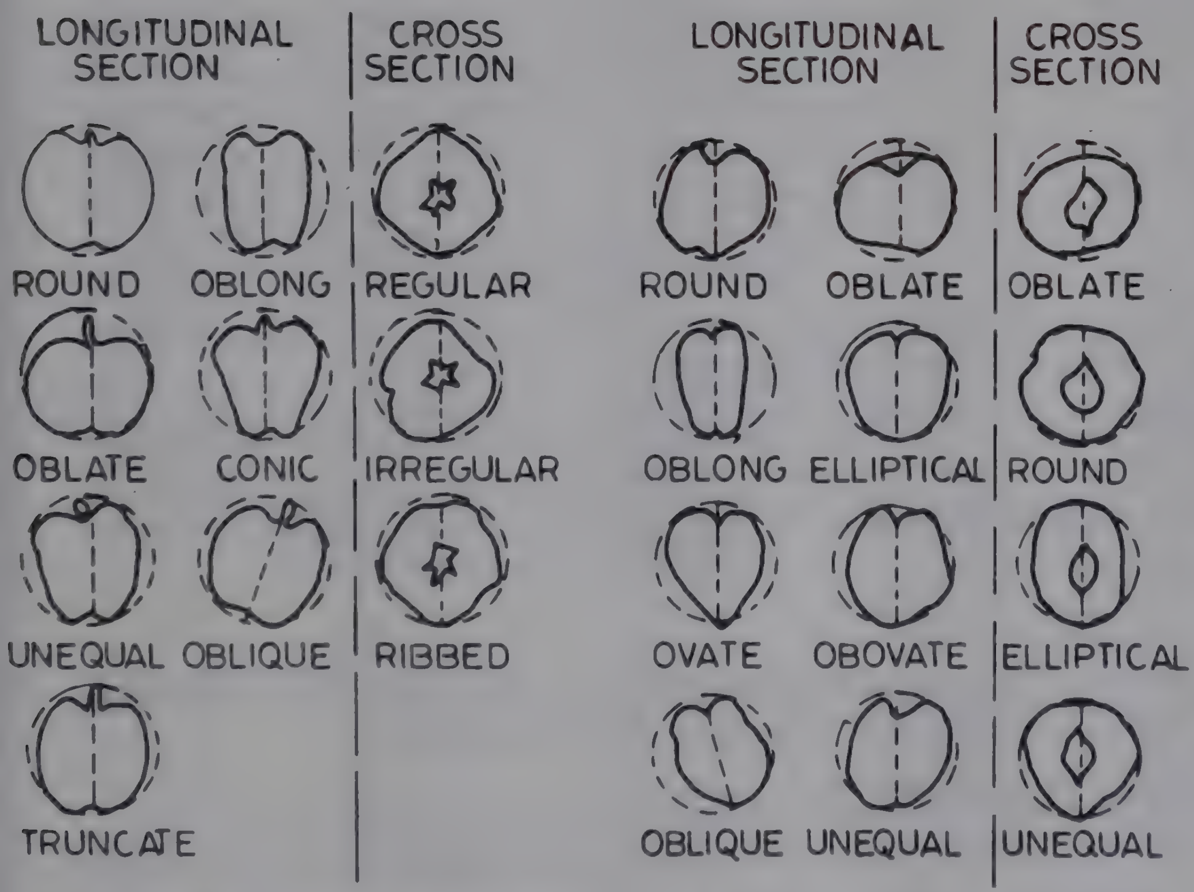


Fig. 2.1. Example of charted standard for describing the shape of an object

Shape defines the form of an object. In defining the shape, some dimensional parameters of an object must be measured. For this, longitudinal and lateral cross sections of the material can be compared with the standard shapes (Fig.2.1).

Using the standards (Fig.2.1), the shape of the product can now be defined by the following descriptive terms (Mohsenin, 1980).

Shape	Description
Round	approaching spheroid
Oblate	flattened at the stem and apex
Oblong	vertical diameter greater than the horizontal diameter
Conic	tapered toward the apex
Ovate	egg shaped and broad at the stem end
Obavate	inverted ovate
Elliptical	approaching ellipsoid
Truncate	having both ends squared or flattened
Unequal	one-half larger than the other
Ribbed	in cross section, sides are more or less angular
Regular	horizontal section approaches a circle
Irregular	horizontal cross section departs materially from a circle

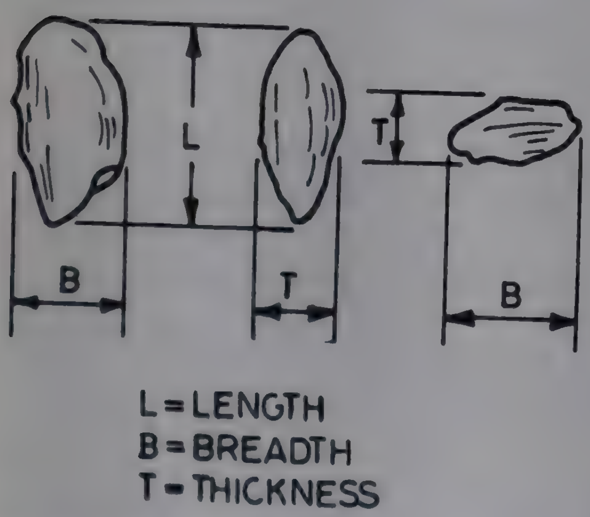


Fig. 2.2. Dimensions of an object

Spatial dimensions of a seed can be measured using micro-meters/projection microscope with suitable least count (say 0.001mm) in case of small seeds, such as, linseed, mustard etc. Projection microscope may be used for measuring the spatial dimensions. The spatial dimensions can also be obtained by measurment of the total length/width of 10 seeds (randomly chosen) arranged in a line tip to tip/touching along with width or maximum diameter (Wratten et al, 1969). This measurement could then be divided by 10 to obtain an average seed length/width.

The longest dimension, 'L' is called length, second longest dimension 'B' perpendicular to 'L' is called breadth and the third longest dimension 'T' perpendicular to both is called thickness of an object (Fig.2.2).

Size or equivalent diameter is the geometric mean of the three dimensions, viz; length, breadth and thickness. Size can be calculated using the following expression:

$$\text{Size} = (\text{length} \times \text{breadth} \times \text{thickness})^{1/3}$$

Sphericity is defined as the ratio of surface area of sphere having same volume as that of the grain to the surface area of the grain.

$$\text{Sphericity} = \frac{d_i}{d_c} \qquad \ldots (2.1)$$

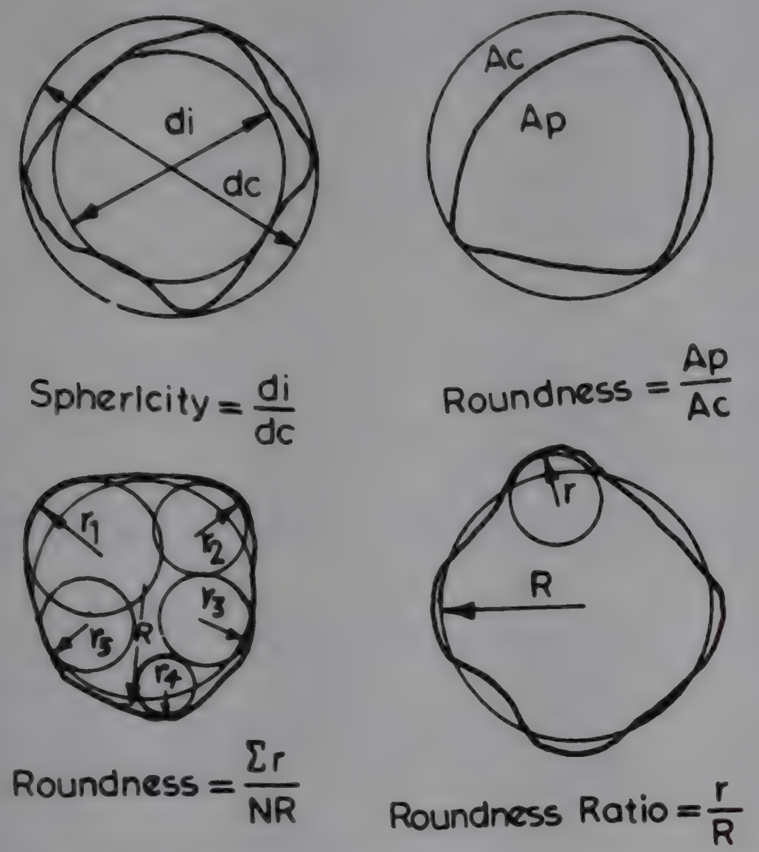


Fig. 2.3. Sphericity and roundness as defined to describe shape of grain (Curray, 1951)

Where, d_i is the diameter of the largest inscribed circle, and d_c is the diameter of the smallest circumscribed circle as shown in Fig. 2.3

For determination of surface area of many spheroidal agricultural objects, the following formula can be used. Surface area 'S' of a prolate spheroid is given by

$$S = 2\pi b^2 + 2\pi \frac{ab}{e} \sin^{-1} e \qquad \ldots (2.2)$$

Where, a and b are, respectively major and minor semiaxes of the ellipse of rotation and

$$e = [1 - (b/a)^2]^{1/2} \qquad \ldots (2.3)$$

Surface area 'S' of an oblate - spheroid is given by

$$S = 2\pi a^2 + \pi \frac{b^2}{e} \ln \frac{(1+e)}{(1-e)} \qquad \ldots (2.4)$$

Where, a, b and e are as defined earlier.

For determination of surface area of paddy grains, assuming them as cono-elliptical cylinders as well as cono-circular cylinders, two different relationships (emperical) have been developed in terms of principal dimension L, B and T (Fig. 2.2) as follows:

$$S = \frac{3}{4} L\pi [\, 3(b+t) - \sqrt{(3b+t)(b+3t)}\,] \qquad \ldots (2.5)$$

$$\text{and } S = \frac{13}{11} (B+T)\, L \qquad \ldots (2.6)$$

Where L, B and T represent length, breadth and thickness, respectively and 'b' and 't' are half the values of B and T.

Roundness is a measure of the bluntness of the corners of an object. Several methods (Mohsenin, 1980) have been proposed for estimating roundness. Some of the selected methods are :

$$\text{Roundness} = \frac{A_p}{A_c} \qquad \ldots (2.7)$$

Where, A_p is the largest projected area of object in natural rest position and A_c is the area of the smallest circumscribing circle. The object area is obtained either by projection or tracing (Fig. 2.3).

$$\text{Roundness} = \frac{\Sigma R}{nR} \qquad \ldots (2.8)$$

Where, r is the radius of curvature as defined in Fig. 1.3, R is the radius of the maximum inscribed circle and n is the total number of corners summed in numerator (Fig.2.3).

$$\text{Roundness ratio} = \frac{r}{R} \qquad \ldots (2.9)$$

Where, R is the mean radius of the object and r is the radius of curvature of the sharpest corner (Fig.2.3).

Moisture content

Moisture content (m.c.) of a substance is defined as the amount of water present in it. It is an index of the probable keeping quality of the product. The amount of moisture in a product is designated on the basis of the weight of water and is usually expressed in per cent. There are two methods of designating the moisture content, viz; wet basis and dry basis. The moisture content on a wet basis (w b) is obtained by dividing the weight of water present in the material by the total weight of the material(Eqn. 2.10).

$$\text{Moisture content, \% (w b)} = \frac{W_w}{W_w + W_d} \times 100 \qquad \ldots (2.10)$$

Where, W_w = weight of water, g and

W_d = weight of dry matter, g.

The moisture content on a dry basis (d b) is determined by dividing the weight of water by the weight of dry matter (Eqn. 2.11).

$$\text{Moisture content, \% (db)} = \frac{W_w}{W_d} \times 100 \qquad \ldots (2.11)$$

The moisture content on a wet basis is used for commercial designation whereas, the dry basis is mainly used by research workers and in equations dealing with moisture variations. The moisture content on the dry basis is always larger than the wet basis. The following relationship can be used for converting the moisture content on one basis to the other :

$$\text{Moisture content, \% (db)} = \frac{\textit{moisture content, \%(w b)}}{100 - \textit{moisture content,\%(w b)}} \times 100 \qquad \ldots \quad (2.12)$$

$$\text{Moisture content, \% (wb)} = \frac{\textit{moisture content, \% (d b)}}{100 + \textit{moisture content, \%(d b)}} \times 100 \qquad \ldots \quad (2.13)$$

Determination of moisture content

The methods of determining the moisture content of products may be divided into two broad classifications: (1) direct and (2) indirect. Direct method includes oven methods, distillation methods and drying with desiccants.

I. Direct methods

Several different oven procedures are available for moisture determination of different materials. The usual procedure is to remove the moisture from the product in an air-oven. When warm or hot water is circulated around the walls to heat the oven by the circulating water, it is called a water-oven. The usual oven methods for moisture determination of grain are ;

A. Air-oven method

1. Single stage; for grain under 13 per cent moisture.
   Grind duplicate samples of 2 to 3 g each. Heat for 1 h at 130°C ± 1°C.
   Place in desiccator, then weigh.
2. Double stage; for grain above 13 per cent moisture.
   Remove moisture of 25 to 30 g samples until it is below 13 per cent (usually about 14 to 16 h are required at 130°C ± 1°C).
   Continue as discussed under (1).

B. Water-oven or Air-oven Method

Place duplicate 25 to 30 g samples in oven, heated to 100°C for 72 - 96 h.

Place in desiccator, then weigh.

Distillation methods

With the distillation methods, moisture is removed by heating the grain in oil and determining the volume or weight of water removed from the grain in condensed vapour or from the loss of weight of the sample.

Drying with desiccants

The moisture content of a product is determined by placing the sample near an efficient drying agent in a closed container with the vapour pressure of the material higher than that of the desiccant, the moisture moves from the material to the drying agent. One standard procedure is to place the sample in a vacuum oven with anhydrous sulphuric acid until constant weight is obtained. This method is particularly useful for materials where dry matter decomposition would be large when the product is heated for extended time.

II. Indirect Methods

Indirect methods involve the measurement of a property of the material which depends upon the moisture content. The moisture content is usually expressed on a wet basis for the indirect methods. All types of moisture meters fall under the indirect methods for moisture measurement. Some of the indirect methods are described as follows :

i. Electrical resistance method

The electrical resistance or conductivity of a material depends upon its moisture content. The electrical resistance varies with moisture, temperature and degree of compaction. This principle is used as a basis for a number of moisture meters.

The useful range of these meters extends up to atleast 25% m.c. Temperature correction is necessary and must be provided in the form of charts or scale adjustments for each class of material.

ii. Capacitance (Impedance) method

The basis of this measurement is the distinctive dielectric characteristic of water, which affects the impedance measurement more strongly than other substances normally present in crop material. The presence of water has a considerable influence on the permittivity or the dielectric constant of the material. Capacitance meters for grain and other seeds are mainly of the high frequency type (MHz frequencies), with compact, solid state circuits, operated by battery power. Their range extends to 30% m.c. in most cases, each class of material requiring its own calibration. Over their normal range, these meters mainly give indications that are within ± 1% m.c. of the standard oven results.

Sample Conditioning

Sometimes, grain samples with desired moisture content are needed for determining the various engineering properties. For this, the following methods could be used to obtain the samples at desired moisture content.

The seeds are moistured with pre-determined quantity of water and periodically stirred in air tight plastic bags. The treated samples are preserved in a refrigerator at 5°C for 5 days to ensure uniform distribution of moisture (Sreenarayanan et al, 1985).

The grain samples of the desired moisture levels are prepared by adding calculated amount of distilled water and sealing in separate polyethylene bags. The samples are kept at 278 K in a refrigerator for atleast a week to enable the moisture to distribute uniformly throughout the sample. Before starting a test, the required quantity of the grain is taken out of the refrigerator and allowed to warm upto the room temperature (Dutta et al, 1988).

The moisture content of the sample prepared using above methods can be verified by standard oven method before starting a test. The following relationship may be used for calculation of the amount of water to be added for sample preparation :

$$W = I\,\frac{(W_2-W_1)}{(100-W_2)} \qquad \ldots \quad (2.14)$$

Where,

W = amount of water to be added, g

I = initial weight of the sample, g

W_1 and W_2 = initial and final moisture content of the sample, %.

However, for determining the moisture content of oilseeds, method as prescribed in IS : 3579-1966, may be used.

Weigh accurately 2.0 ± 0.5 g of the sample in a moisture dish which has been dried previously, cooled in the desiccator and then weighed. Place the dish in the air oven for approximately one hour at 105 ± 1°C. Remove the dish from the oven, cool in the desiccator to room temperature and weigh. Repeat this procedure but keep the dish in the oven only for half an hour each time until the difference between the two successive weighings does not exceed one mg.

Various research workers have carried out studies on the physical properties for cereals (corn, finger millet, minor millets, paddy, pearl millet, rice, sorghum and wheat); pulses (black gram, Bengal gram, cowpea, greengram, lentil, pea and pigeon pea) ; oilseeds (castor, groundnut, linseed, mustard, niger, safflower, soybean and sunflower), fruit/vegetable seeds (brinjal, long melon, musk melon, pumpkin, summer melon, tomato and water melon) and spices (aniseed, coriander seed, cumin seed, fenugreek seed and turmeric rhyzome) for Indian varieties at different moisture contents. Some of these properties such as, spatial dimension, size, sphericity, projected area and surface area are listed in the Tables 2.1–2.5.

Table 2.1 : Spatial dimensions, size and spericity of cereal grains

Grain/Variety	Moisture content, %(db)	Length, mm	Width /dia, mm	Thick-ness, mm	Size, mm	Sphericity	Reference
1.	2.	3.	4.	5.	6.	7.	8.
Bajra							16,41
HB-1	8.7	3.10	1.95	1.87	2.24	0.72	
	12.4	3.11	2.03	1.99	2.33	0.75	
	16.3	3.23	2.13	2.11	2.44	0.76	
	20.5	3.14	2.18	2.19	2.47	0.79	
	25.0	3.31	2.38	2.32	2.63	0.80	
Corn (maize)							16,41
Ganga-5	8.7	8.67	7.07	5.45	6.94	0.80	
Small category	12.4	8.84	7.14	5.57	7.06	0.80	
	16.3	9.11	7.60	5.64	7.31	0.80	
	20.5	9.28	7.91	5.99	7.54	0.81	
	25.0	8.93	8.06	6.55	7.78	0.87	
Medium category	8.7	10.47	8.44	3.91	7.02	0.67	
	12.4	10.80	9.37	4.05	7.43	0.69	
	16.3	10.85	9.26	4.20	7.50	0.69	
	20.5	10.98	9.08	4.26	7.52	0.69	
	25.0	11.34	9.52	4.48	7.85	0.69	
Large category	8.7	11.99	8.36	4.97	7.93	0.66	
	12.4	12.12	8.52	4.21	7.58	0.63	
	16.3	12.16	8.80	4.33	7.74	0.64	
	20.5	12.24	8.90	4.47	7.87	0.64	
	25.0	12.33	9.24	4.69	8.12	0.66	
Malan							
Small category	8.7	7.93	7.99	4.09	6.38	0.80	
	12.4	8.13	8.05	4.17	6.49	0.80	
	16.3	8.17	8.04	4.05	6.43	0.79	
	20.5	8.18	7.98	3.94	6.36	0.78	
	25.0	8.16	7.99	4.04	6.41	0.79	
Medium category	8.7	9.11	8.44	4.37	6.95	0.76	
	12.4	9.36	8.58	4.41	7.08	0.76	
	16.3	9.42	8.63	4.38	7.09	0.75	
	20.5	9.30	8.48	4.45	7.05	0.76	
	25.0	9.47	8.63	4.25	7.02	0.74	
Large category	8.7	10.51	9.88	4.38	7.69	0.73	
	12.4	10.52	9.78	4.54	7.76	0.74	
	16.3	10.58	9.57	4.42	7.65	0.72	

Table Contd...

1.	2.	3.	4.	5.	6.	7.	8.
	20.5	10.69	9.42	4.29	7.65	0.71	
	25.0	10.91	9.45	4.47	7.72	0.71	
MOC-5	—	9.17	6.99	—	—	—	
Finger millet							
Co-11	—	1.45	1.33	—	—	—	41
Kodu							173
GPLM-52	—	—	—	—	1.53	0.99	
IPS-147-5	—	—	—	—	1.23	0.47	
JK-41	—	—	—	—	2.01	0.75	
JK-62	—	—	—	—	2.12	0.77	
RPS-76	—	—	—	—	1.98	0.77	
Kutki							173
JK-8	—	—	—	—	1.50	0.70	
RPC-3	—	—	—	—	1.45	0.73	
RPM-85-1	—	—	—	—	1.50	0.67	
Paddy							10,33
ADT-3	11.2	7.57	3.00	2.09	3.48	0.46	
ADT-4	11.2	7.87	3.13	2.05	3.70	0.47	
ADT-10	12.7	7.28	3.00	2.03	3.54	0.49	
ADT-11	12.9	7.32	2.92	2.07	3.54	0.48	
ADT-16	11.6	7.00	2.08	1.69	2.91	0.42	
ADT-20	12.1	6.00	2.84	1.95	3.22	0.54	
ADT-22	13.2	8.08	2.91	2.12	3.68	0.46	
ADT-27	8.2	5.98	2.60	1.99	3.13	0.52	
	8.8	5.93	2.81	2.00	3.22	0.54	
	11.6	6.12	3.08	2.03	3.37	0.55	
ADT-28	12.1	7.95	3.17	2.25	3.34	0.50	
ADT-31	10.6	7.64	3.40	1.97	3.71	0.49	
ASD-1	11.1	7.80	3.08	2.24	3.78	0.48	
ASD-5	11.7	7.78	2.56	2.00	3.42	0.44	
ASD-8	9.9	7.48	3.00	2.16	3.65	0.49	
ASD-10	14.2	7.96	3.28	2.25	3.89	0.49	
ASD-11	12.1	8.40	2.50	2.84	3.91	0.47	
Akkulla	13.8	8.01	2.51	1.79	3.30	0.41	
	18.0	8.04	2.52	1.80	3.32	0.41	
	19.7	8.08	2.54	1.80	3.32	0.41	

Table Contd...

1.	2.	3.	4.	5.	6.	7.	8.
	22.8	8.12	2.54	1.84	3.36	0.41	
	24.1	8.17	2.56	1.85	3.38	0.41	
Annapoorna	10.9	8.25	3.04	2.05	3.72	0.45	
Anupama	11.8	8.91	2.68	2.01	3.63	0.41	
Aswathi	11.0	8.80	3.14	2.11	3.88	0.44	
BAM-3	11.5	8.41	2.64	2.00	3.54	0.42	
Bala	12.0	6.40	2.78	1.92	3.26	0.51	
Basmati	13.6	10.05	2.30	1.83	3.49	0.35	
Basumathi	—	9.40	2.55	1.90	3.57	0.38	
BC-11-6-3	13.7	9.75	3.35	2.06	4.07	0.42	
Bhavani	11.4	8.26	2.48	1.89	3.38	0.41	
Cavery	—	8.19	2.27	1.84	3.44	0.42	
CH-2	12.4	7.83	3.21	2.00	3.69	0.47	
CH. Sx O. 16	11.4	8.09	2.17	1.72	3.11	0.39	
CR. 12-178	13.3	8.18	2.50	1.98	3.43	0.42	
CO 1	12.7	8.21	2.75	2.03	3.58	0.44	
CO 2	12.6	7.48	2.84	1.95	3.46	0.46	
CO 4	11.4	8.86	2.86	2.18	3.81	0.43	
CO 7	13.4	9.58	2.89	2.01	3.82	0.43	
CO 8	10.9	8.81	2.52	1.96	3.52	0.40	
CO 10	11.0	8.40	3.05	2.12	3.70	0.45	
CO 13	10.9	7.92	3.08	2.15	3.74	0.47	
CO 16	12.5	7.54	2.88	2.02	3.53	0.47	
CO 18	10.9	8.18	2.91	2.02	3.64	0.45	
CO 19	12.0	7.50	2.75	2.14	3.53	0.47	
CO 25	7.8	6.84	3.09	2.00	3.48	0.51	
	11.1	6.44	2.88	2.13	3.41	0.53	
CO 26	12.1	6.76	2.88	2.04	3.41	0.53	
CO 29	10.7	8.00	2.91	2.09	3.65	0.46	
CO 30	12.4	7.66	2.54	1.88	3.32	0.43	
CO 32	12.7	7.45	2.58	1.93	3.34	0.45	
CO 33	9.2	6.02	2.96	1.95	3.26	0.54	
	11.9	5.79	3.03	2.10	3.32	0.58	
CO 34	11.6	7.32	2.85	2.05	3.50	0.48	
CO 36	11.6	7.60	2.64	1.89	3.36	0.44	
CO 37	12.0	7.84	2.80	1.99	3.52	0.45	

Table Contd...

1.	2.	3.	4.	5.	6.	7.	8.
Desal	11.2	7.36	2.96	2.05	3.55	0.48	
Gettu	11.9	7.91	2.95	2.00	3.60	0.46	
GEB—24	12.0	7.54	2.31	1.79	3.15	0.42	
IET-1039	12.5	8.80	2.14	1.81	3.24	0.37	
IET-2222	11.5	9.14	2.91	1.96	3.74	0.41	
IET-2585	12.9	7.54	2.70	1.97	3.42	0.45	
IR 5	15.9	7.43	3.15	1.97	3.58	0.48	
	11.0	8.36	3.22	2.13	3.86	0.46	
IR 8	7.8–23.0	8.70	3.09	1.99	3.76	0.43	
	11.2	9.00	3.14	2.13	3.92	0.44	
IR 20	7.8–23.0	7.64	2.46	1.76	3.21	0.42	
	10.9	8.04	2.56	1.86	3.37	0.42	
IR 24	11.1	8.80	2.60	2.00	3.58	0.41	
IR 26	12.2	7.80	2.64	1.90	3.49	0.44	
Jaya	10.7	8.46	2.52	1.76	3.27	0.42	
	14.6	9.02	3.03	1.98	3.78	0.41	
	16.4	9.34	3.11	1.91	3.81	0.41	
	18.7	9.39	3.13	1.91	3.83	0.41	
	21.1	9.50	3.14	1.93	3.86	0.41	
	22.6	9.55	3.15	1.94	3.88	0.41	
	24.8	9.59	3.16	1.95	3.90	0.41	
	—	8.96	3.01	2.06	3.81	0.42	
Jagannath	12.4	7.50	2.70	2.02	3.45	0.46	
	16.1	7.08	2.57	1.76	3.18	0.45	
	18.1	7.12	2.57	2.77	3.70	0.52	
	21.3	7.17	2.59	1.77	3.20	0.45	
	23.8	7.21	2.60	1.78	3.22	0.45	
	25.8	7.26	2.61	1.80	3.24	0.45	
Kakitya	11.0	7.68	3.00	1.94	3.55	0.46	
Kannagi	12.4	7.71	2.96	2.04	3.60	0.47	
Karikala	10.9	7.04	3.20	2.44	3.80	0.54	
Krishna	10.7	8.33	2.71	1.92	3.51	0.42	
Massori	13.6	7.68	2.46	1.70	3.18	0.41	
	17.0	7.72	2.47	1.71	3.20	0.41	
	20.9	7.77	2.51	1.73	3.23	0.42	
	23.9	7.82	2.51	1.74	3.24	0.42	

Table Contd...

1.	2.	3.	4.	5.	6.	7.	8.
	27.4	7.86	2.52	1.76	3.27	0.42	
Mozhi Karuppm	11.1	8.27	3.52	2.59	4.11	0.50	
N—12	—	8.96	2.19	1.62	3.16	0.35	
No. 16—17	15.2	10.09	2.85	1.89	3.79	0.38	
	17.2	10.13	2.86	1.91	3.81	0.38	
	19.3	10.20	2.88	1.92	3.82	0.37	
	25.8	10.32	2.90	1.94	3.87	0.38	
	28.7	10.40	2.91	1.95	3.89	0.37	
Padma	11.0	8.12	2.79	1.68	3.36	0.41	
Pankaj	11.1	7.34	3.12	2.13	3.65	0.50	
Patnai Local	14.0	8.15	2.80	1.89	3.51	0.43	
Patnai—23	14.6	10.88	2.57	2.03	3.85	0.35	
Pennai	10.9	7.34	3.12	2.13	3.65	0.50	
PLR—1	12.2	7.50	2.72	2.00	3.44	0.46	
PLR—2	12.2	8.66	3.04	2.12	3.82	0.44	
PTB—10	12.1	7.91	2.91	2.01	3.59	0.45	
PTB—15	12.9	7.79	2.58	1.90	3.37	0.43	
PUR—1	11.4	8.09	2.95	2.07	3.67	0.45	
Ratna	10.9	7.34	2.60	2.05	3.40	0.46	
	12.1	8.45	2.34	1.77	3.33	0.37	
	—	9.34	2.33	1.86	3.43	0.36	
RP4—14	12.9	9.05	2.55	3.54	4.34	0.48	
RP 172—2	12.9	8.82	3.05	2.09	3.83	0.43	
RP 176—5	14.4	8.52	2.65	1.88	3.49	0.41	
Rohini	10.7	9.05	3.00	2.02	3.80	0.42	
Sabarmathi	10.9	7.65	2.65	1.97	3.42	0.45	
Saket—4	—	9.14	2.38	1.83	3.41	0.37	
Sona	10.9	9.28	2.00	1.82	3.23	0.35	
Thallahamsa	11.5	9.29	2.57	2.08	3.68	0.40	
Thillarnaya-gam (Paramakudi)	11.4	7.71	3.27	2.31	3.88	0.50	
Thillarnaya-gam (Peravurni)	13.1	7.71	3.29	2.31	3.88	0.51	
TKM—4	10.5	8.66	2.21	1.97	2.58	0.30	
TKM—5	10.9	8.05	3.00	2.05	3.67	0.46	
TKM—6	24.0	8.12	2.33	1.79	3.23	0.40	

Table Contd...

1.	2.	3.	4.	5.	6.	7.	8.
TNR—2	11.0	8.38	2.36	1.86	3.33	0.40	
	13.3	8.21	3.30	2.20	3.91	0.48	
Triveni	10.9	8.12	3.04	2.03	3.69	0.45	
Type—3	—	9.16	2.06	1.77	3.22	0.35	
Vijaya	11.7	7.60	2.64	1.95	3.40	0.45	
633	14.3	7.64	2.92	1.99	3.54	0.46	
658	12.5	7.40	2.76	2.04	3.47	0.47	
688	13.0	7.40	3.00	1.98	3.53	0.48	
4611	12.7	8.00	2.67	1.88	3.42	0.43	
4614	14.5	8.35	3.04	2.07	3.75	0.45	
6464	14.0	7.40	3.28	2.22	3.78	0.51	
6534	13.6	7.83	3.63	2.67	3.89	0.50	
6543	13.4	7.76	3.04	1.99	3.61	0.47	
6547	14.1	7.72	3.04	2.01	3.61	0.47	
7711	13.1	8.30	2.52	2.00	3.47	0.42	
8111	13.6	7.32	2.64	1.89	3.32	0.45	
Pearlmillet							41
CO—6	—	3.21	2.27	—	—	—	
Rice							10,33
Basmati	—	7.50	1.95	—	—	—	
B.S.	—	6.15	2.00	—	—	—	
Ch 45	—	6.30	2.65	—	—	—	
Gansali	—	4.30	2.15	—	—	—	
GEB—24	—	5.95	2.20	—	—	—	
GMR 2	—	7.35	2.65	—	—	—	
Gowri Sanna	—	5.50	2.20	—	—	—	
Halubbulu	—	6.25	2.40	—	—	—	
Intan	—	6.60	2.45	—	—	—	
IR 8	—	6.75	2.65	—	—	—	
IR 20	—	5.95	2.15	—	—	—	
J—65	—	5.15	3.05	—	—	—	

Table Contd...

1.	2.	3.	4.	5.	6.	7.	8.
Jaya	—	6.45	2.65	—	—	—	
Jenugoodu	—	6.10	1.85	—	—	—	
Jeerasali	—	4.35	1.90	—	—	—	
Madhu	—	6.05	2.25	—	—	—	
Mangala	—	6.20	2.60	—	—	—	
Peta	—	6.55	2.55	—	—	—	
Prakash	—	6.95	2.15	—	—	—	
Pushpa	—	7.20	2.20	—	—	—	
S—701	—	6.45	2.15	—	—	—	
Sona	—	6.70	1.95	—	—	—	
SR 26 B	—	8.35	2.35	—	—	—	
Sukandi	—	5.45	2.85	—	—	—	
Vani	—	6.45	2.05	—	—	—	
Sawan							173
REF—51—1	—	—	—	—	2.05	0.72	
REF—79—1	—	—	—	—	1.89	0.70	
Sorghum							36,38
CSH—5	25.0	4.23± 0.10	3.80 ± 0.52	2.46 ± 0.14	3.41	0.31	
CSH—8R	25.0	4.91± 0.16	4.49 ± 0.28	2.70 ± 0.08	3.90	0.80	
CHS—202	25.0	4.74 ± 0.10	4.70 ± 0.18	2.90 ± 0.11	4.01	0.85	
CO—627	—	4.25	3.83	—	—	—	
M—35—1	25.0	5.03 ± 0.21	4.73 ± 0.15	3.35 ± 0.14	4.30	0.86	
SPU—86	25.0	5.03 ± 0.18	4.45 ± 0.15	3.15 ± 0.11	4.13	0.82	
Wheat							15,41
HD—2189	—	6.08	2.92	—	—	—	
WH—147	6.7	6.81	3.09	2.77	3.88	0.57	
WS—147	—	6.81 ± 1.06	3.09 ± 0.22	2.77 ± 0.24	3.88	0.57	

Table 2.2 : Spatial dimensions, size and sphericity of pulses

Grain/ Variety	Moisture content, % (db)	Length, mm	Width, mm	Thickness, mm	Size, mm	Sphericity	Reference
1.	2.	3.	4.	5.	6.	7.	8.
Bengal gram							41,52
BR—77	—	8.56	6.25	5.96	6.83	0.80	
CS—24	7.5	7.16	5.18	5.08	5.73	0.80	
	13.6	7.73	5.64	5.32	6.14	0.79	
	22.0	8.04	6.21	5.65	6.56	0.82	
	31.6	8.15	6.57	6.11	6.89	0.85	
JG-74	14.9	—	—	—	6.48	0.78	
Local	8.8	—	—	—	0.29	0.34	
L—550	14.9	—	—	—	6.20	0.87	
Ujjain—21	7.9	8.22	5.77	5.55	6.41	0.81	
Ujjain	14.9	—	—	—	6.03	0.80	
Black gram							143
DU—1	—	4.77	3.72	3.13	3.82	—	
DU—2	—	4.12	3.41	3.04	3.50	—	
DU—3	—	4.23	3.53	3.12	3.61	—	
DU—4	—	4.20	3.60	3.16	3.63	—	
JU—77—41	—	4.50	3.57	3.09	3.69	—	
JU—78—3	—	4.17	3.43	3.07	3.53	—	
JU—78—27	—	4.20	3.43	3.05	3.53	—	
Khargone—3	—	4.55	3.73	3.17	3.78	—	
Local	7.6	—	—	—	3.78	0.78	
N—55	—	4.35	3.51	3.13	3.63	—	
Pant—U—30	—	4.19	3.39	3.12	3.54	—	
PDU—1	—	4.68	3.88	3.02	3.80	—	
PDU—3	—	3.80	3.34	3.10	3.75	—	
PU—26	—	4.47	3.57	3.17	3.70	—	
PU—30	—	4.25	3.26	2.85	3.41	—	
RU—2	—	4.30	3.58	3.16	3.65	—	
Sardomogh	—	4.22	3.52	3.11	3.59	—	
T—9	7.5	4.47	3.35	2.88	3.51	0.79	
	13.6	4.67	3.41	2.89	3.58	0.77	
	22.0	4.80	3.55	3.08	3.74	0.78	
	31.6	4.91	3.79	3.31	3.95	0.80	
	—	4.18	3.45	3.12	3.56	—	

Table Contd...

1.	2.	3.	4.	5.	6.	7.	8.
UG—201	—	4.16	3.44	3.06	3.53	—	
UG—218	—	4.31	3.62	3.13	3.66	—	
UH—28	—	4.48	3.65	3.14	3.72	—	
UH—80—4	—	3.98	3.62	3.15	3.57	—	
UH—80—7	—	4.45	3.66	3.22	3.74	—	
UPU—80—3—5	—	4.31	3.64	3.28	3.72	—	
UPU—83—2	—	4.18	3.58	3.18	3.62	—	
UPG—82—5	—	4.27	3.46	3.14	3.59	—	
727	—	4.87	3.90	3.37	4.00	0.76	
Cowpea							41
Local	7.2	—	—	—	5.35	0.73	
T—2	—	7.83	6.11	4.70	6.08	0.77	
Green gram							143
HB—45	—	3.86	3.18	3.11	3.37	0.86	
J—45	—	4.16	3.25	3.15	3.49	—	
K—851	—	4.25	3.16	3.16	3.49	—	
Kopargaon	—	4.80	3.63	3.49	3.93	—	
Local	7.2	—	—	—	3.54	0.84	
MH—81—7	—	4.17	3.14	3.04	3.46	—	
MH—309	—	4.15	2.98	2.98	3.33	—	
Pant Mung—2	—	4.32	3.11	2.97	3.42	—	
Pb	7.5	4.43	3.54	3.43	3.78	0.76	
	13.6	4.49	3.55	3.45	3.80	0.76	
	22.0	4.94	3.61	3.48	3.96	0.75	
	31.6	5.17	3.85	3.76	4.21	0.72	
PS—16	—	3.76	2.92	2.70	3.10	—	
Pusa Baisakhi	—	4.06	3.26	3.10	3.45	—	
Puss—105	—	3.82	3.09	2.98	3.10	—	
Rahuri—1	—	4.46	3.23	3.08	3.54	—	
UPM—82—4	—	4.03	3.00	2.91	3.28	—	
UPM—83—10	—	4.03	3.01	2.95	3.30	—	
11—395	—	4.25	3.20	3.07	3.47	—	
Horse gram (local)	—	5.56	3.85	2.23	2.56	0.41	173
Lentil							48, 52
L—9—12	7.5	3.59	3.43	2.25	3.03	0.84	
	13.6	3.63	3.47	2.29	3.07	0.85	
	22.0	3.72	3.65	2.37	3.18	0.85	
	31.6	4.13	3.99	2.43	3.42	0.83	

Table Contd...

1.	2.	3.	4.	5.	6.	7.	8.
Local	8.9	—	—	—	3.03	0.80	
Local (Malka Masur)	8.5	—	—	—	3.46	0.80	
Pea							41
Bonniville	—	8.36	6.65	5.92	5.90	0.82	
VRS—615	—	6.80	6.43	6.04	6.44	0.95	
Pigeon pea							41,52,173
C—11	—	6.56	5.30	4.63	5.44	0.89	
ICPL—1	13.6	—	—	—	4.92	0.92	
ICPL—6	13.6	—	—	—	4.75	0.84	
ICPL—87	13.6	—	—	—	4.91	0.85	
ICPL—131	13.6	—	—	—	4.76	0.87	
ICPL—138	13.6	—	—	—	4.80	0.88	
ICPL—211	13.6	—	—	—	5.94	0.90	
ICPL—227	13.6	—	—	—	4.90	0.88	
ICPL—270	13.6	—	—	—	5.22	0.84	
ICPL—332	13.6	—	—	—	4.40	0.85	
ICPL—333	13.6	—	—	—	5.11	0.90	
ICPL—7035	13.6	—	—	—	6.72	0.89	
ICPL—84060	13.6	—	—	—	4.77	0.87	
JA—3	6.2	5.97	4.59	4.16	—	—	
	7.5	5.88	5.07	4.23	5.02	0.85	
	13.6	6.17	5.09	4.28	5.12	0.83	
	22.0	6.62	5.22	4.48	5.38	0.81	
	31.6	6.92	5.65	4.48	5.76	0.83	
Local	9.5	—	—	—	4.08	0.68	
Pigeon pea (p od)							173
UPAS—20	11.3	—	—	—	—	19.8*	
	11.5	—	—	—	—	20.0*	
	11.6	—	—	—	—	20.5*	
	12.7	—	—	—	—	25.5*	
	13.8	—	—	—	—	20.7*	
	14.2	—	—	—	—	20.5*	
	14.4	—	—	—	—	21.2*	
	16.4	—	—	—	—	23.7*	
	16.5	—	—	—	—	21.7*	
	19.3	—	—	—	—	25.9*	
	19.9	—	—	—	—	27.5*	
	20.3	—	—	—	—	27.0*	

* Surface area, mm^2

Table 2.3 : Spatial dimensions, size and sphercity of oil seeds

Oilseed/Variety	Moisture content, % (db)	Length, mm	Width/dia, mm	Thickness, mm	Size, mm	Sphericity	Reference
1.	2.	3.	4.	5.	6.	7.	8.
Castor							51,54
Local							
Small	5.4	9.98	6.94	5.15	7.09	0.71	227.1*
Medium	5.3	17.82	10.23	6.80	10.74	0.60	606.2*
Large	4.9	17.39	13.21	7.33	11.89	0.68	817.3*
NPH—1	7.5	9.98	6.85	5.07	7.02	0.70	
	13.6	10.10	6.92	5.10	7.09	0.70	
	21.9	10.14	6.97	5.16	7.16	0.75	
	31.6	10.68	6.99	5.30	7.34	0.69	
Groundnut (kernel)							41,53
G—11	7.5	15.85	7.56	6.84	9.36	0.61	
	13.6	16.11	8.02	6.99	9.67	0.60	
	21.9	16.20	8.27	7.57	10.05	0.62	
	31.6	17.65	8.38	7.61	10.40	0.59	
Local							
	6.2	—	—	—	8.53	313.7*	
	8.5	—	—	—	8.97	357.5*	
	10.2	—	—	—	9.14	337.9*	
RS—1	—	14.45	8.74	7.50	9.82	0.69	
TG—3	7.5	12.47	6.88	6.33	8.16	0.65	
	13.6	12.66	7.39	6.96	8.81	0.69	
	21.9	13.75	8.14	7.09	9.21	0.67	
	31.6	14.35	8.45	8.12	9.48	0.66	
Groundnut (pod)							10,75,137
GAUG–1	5.3	21.79	10.42	10.26	13.26	0.61	
	13.6	22.06	10.65	10.39	13.46	0.61	
	20.5	23.37	11.32	10.78	14.18	0.61	
	28.2	24.02	11.66	10.98	14.54	0.61	
GAUG–10	5.3	28.40	10.98	12.58	15.77	0.56	
	13.6	28.71	11.21	12.86	15.06	0.56	
	20.5	30.03	11.69	13.80	16.92	0.56	
	28.2	30.76	11.81	14.26	17.30	0.57	

* Surface area, mm^2

Table Contd...

1.	2.	3.	4.	5.	6.	7.	8.
GG-2	5.3	23.76	11.24	11.44	14.51	0.61	
	13.6	24.13	11.56	11.66	14.82	0.61	
	20.5	25.46	12.27	12.11	15.68	0.61	
	28.2	26.10	12.74	12.20	15.95	0.61	
GG-11	5.3	31.36	12.02	14.12	17.46	0.56	
	13.6	31.83	12.33	14.57	17.80	0.56	
	20.5	33.21	12.86	15.50	18.78	0.57	
	28.2	34.00	12.94	15.93	19.14	0.56	
JL–24–1							
Single kernel ellipsoid	10.3	18.25	11.53	12.55	13.82	0.76	616.3*
Double kernel ellipsoid	10.3	27.17	12.61	11.47	15.78	0.58	1009.3*
Paired ellipsoids	10.3	33.61	11.22	12.28	16.67	0.50	1110.3*
Cassinoids	10.3	28.09	—	11.15	15.17	0.54	1019.9*
Triple kernel ellipsoid	10.3	42.15	11.28	11.99	17.86	0.42	1434.2*
M-13	5.3	33.52	12.70	14.32	18.27	0.55	
	13.6	34.00	12.92	14.77	18.65	0.54	
	20.5	35.39	13.44	15.62	19.51	0.55	
	28.2	36.31	13.53	16.09	19.92	0.55	
Pol—1	—	38.70	11.00	10.70	16.58	0.43	
TMV—1	—	28.95	11.92	10.89	15.55	0.54	
TMV—3	—	23.55	11.42	10.94	14.32	0.61	
TMV—7	—	23.55	12.21	11.43	14.87	0.63	
Linseed							20,173
JL—23—10	—	—	—	—	2.20	0.49	
LC—54	5.5	4.64	2/30	1.20	2.34	0.48	
	11.9	4.76	2.38	1.13	2.34	0.49	
	19.2	5.00	2.41	1.18	2.42	0.48	

* Surface area, mm^2

Table Contd...

1.	2.	3.	4.	5.	6.	7.	8.
	28.9	5.19	2.55	1.22	2.53	0.48	
	39.5	5.27	2.79	1.35	2.08	0.51	
LC—185	5.5	4.50	2.18	0.98	2.13	0.47	
	11.9	4.61	2.23	1.03	2.20	0.47	
	19.2	4.77	2.28	1.07	2.27	0.47	
	28.9	4.85	2.35	1.12	2.34	0.48	
	39.5	5.00	2.40	1.16	2.41	0.48	
R—7	7.5	5.09	2.40	1.11	2.39	0.47	
	13.6	5.17	2.45	1.17	2.46	0.48	
	21.9	5.25	2.58	1.21	2.54	0.48	
	31.6	5.28	2.67	1.23	2.59	0.49	
T—59	6.8	5.54	2.61	1.17	2.57	0.46	
Mustard							9,78
Pusa bold	7.7	—	1.98	—	1.98	0.98	
	8.0	—	2.30	—	2.30	0.98	
	13.6	—	2.00	—	2.00	0.98	
	21.9	—	2.04	—	2.04	0.97	
	31.6	—	2.11	—	2.11	0.96	
Niger seed							78
Local	10.1	3.98±0.52	0.99±0.22	0.70±0.19	1.40	0.36	
Safflower							9,78
JSF—1	6.9	9.31	4.20	3.30	5.00	0.54	
	7.5	8.93	4.67	4.33	5.65	0.63	
	13.6	9.24	4.95	4.38	5.85	0.63	
	21.9	9.43	5.13	4.48	6.01	0.64	
	31.6	9.67	5.21	4.58	6.13	0.63	
Soybean							37,41,143
Ankur	—	—	—	—	5.83	0.86	
Bragg	—	—	—	—	6.74	0.85	
DS—76—1—	—29	—	—	—	5.46	0.85	
JS—2	7.5	7.85	7.15	5.89	6.92	0.88	
	13.6	8.10	7.30	6.12	7.13	0.88	

Table Contd...

1.	2.	3.	4.	5.	6.	7.	8.
	21.9	9.69	7.34	6.14	7.59	0.78	
	31.6	9.79	7.68	6.23	7.77	0.79	
JS—7244	11.3	7.71±1.02	6.12±0.64	4.80±0.65	6.10	0.79	
	8.7	6.32	5.23	3.99	5.09	0.81	81.3*
	10.4	6.33	5.26	4.07	5.13	0.81	82.8*
	14.6	6.49	5.35	4.19	5.26	0.81	87.0*
	16.4	6.58	5.45	4.25	5.34	0.81	89.6*
	21.8	6.64	5.52	4.34	5.42	0.82	92.2*
	25.0	6.75	5.55	4.45	5.51	0.82	95.2*
JS—75—19	—	—	—	—	5.86	0.86	
JS—75—45	—	—	—	—	5.77	0.86	
JS—76—205	—	—	—	—	5.80	0.87	
JS—76—259	—	—	—	—	5.36	0.83	
JS—76—280	—	—	—	—	5.22	0.82	
JS—80—21	—	—	—	—	5.40	0.82	
Kalituar	—	—	—	—	5.08	0.80	
Lee	—	7.29	6.84	5.88	6.64	0.91	
MACS—75	—	—	—	—	5.54	0.84	
N—19	—	—	—	—	5.88	0.92	
PK—472	—	—	—	—	5.95	0.90	
Punjab—1	—	7.02	6.29	5.05	6.06	0.87	
T—49	—	—	—	—	4.83	0.81	
Sunflower (head)							113
Morden	—	—	107.00	17.00	—	0.87	
Sunflower (seed)							9,41,78
GD—1	—	9.5	3.80	2.50	4.42	0.47	
KBSH—1	—	10.9	4.30	2.70	4.94	0.45	
Morden	7.7	10.33	5.28	2.95	5.44	0.53	
	9.2	10.59	4.19	2.81	5.00	0.47	
	—	11.00	4.40	2.90	5.11	0.46	
	13.6	11.57	5.57	3.87	6.13	0.54	
	21.9	11.60	6.14	4.25	6.72	0.58	
	31.6	12.28	6.42	4.47	7.06	0.58	
RHA—274	—	9.3	3.90	2.50	4.43	0.48	

* Surface area, mm^2

Table 2.4 : Spatial dimensions, size, sphericity and surface area of fruit and vegetable seeds

Seed/Variety	Moisture content, % (db)	Length, mm	Width, mm	Thickness, mm	Size, mm	Sphericity	Surface area, mm^2	Reference
1.	2.	3.	4.	5.	6.	7.	8.	9.
Brinjal								148
Local	3.6	2.64± 0.21	2.08± 0.36	0.73± 0.07	1.59 ± 0.13	0.61 ± 0.06	0.61 ± 0.05	
Cassava (tuber)								173
Deskinned tuber	—	—	40.12	—	—	—	—	
Whole tuber								
H 165	—	154.00	—	86.60	—	—	—	
Local	—	—	42.37	—	—	—	—	
Grape (whole fruit)								173
Berry	—	146.00	141.00	—	—	—	—	
Bunch	—	201.50	121.50	—	—	—	—	
Long melon								127
Min.	—	6.50	2.50	0.70	2.25	0.35	—	
Max.	—	9.60	3.70	1.00	3.29	0.34	—	
Av.	—	7.90	3.10	1.00	2.90	0.37	—	
Gorgon nut (Makhana)								70
Local	15–60	—	—	—	6.54–12..91	0.99	—	
Mango stone	—	62.00	30.00	19.00	31.70	0.51	—	173
Mango whole fruit	—	72.60	51.40	52.60	55.80	0.77	—	173
Marking nut								8
Large with flower	—	27.2	18.4	11.7	—	—	—	
Large without flower	—	21.7	18.6	10.3	—	—	—	
Medium with flower	—	25.8	16.5	11.5	—	—	—	
Medium without flower	—	19.4	16.6	9.9	—	—	—	
Small with flower	—	22.3	15.8	9.9	—	—	—	
Small without flower	—	17.6	15.2	9.6	—	—	—	

Table Contd...

1.	2.	3.	4.	5.	6.	7.	8.	9.
Musk melon								127
Min.	—	7.10	3.00	0.90	2.68	0.38	—	
Max.	—	11.70	4.60	1.40	4.22	0.36	—	
Av.	—	9.50	3.80	1.10	3.41	0.36	—	
Peach fruit	—	55.10	52.70	—	—	—	—	173
Pomegranate seed	—	—	0.40	—	—	—	—	173
Potato								
Kufri Chandramukhi	325.5	—	—	—	52.0	0.79	—	173
Pumpkin								148
Local	10.9	19.00± 1.19	10.04 ± 1.19	2.64 ± 0.31	7.92 ± 0.60	0.42 ± 0.02	13.33 ± 2.68	
Ridge-gourd fruit	—	178.10	39.30	—	—	—	—	173
Ridge-gourd vine	—	51.70	—	—	—	—	—	
Summer melon								148
Local	4.5	10.70± 0.85	4.35 ± 0.74	1.54 ± 0.23	4.11 ± 0.31	0.39 ± 0.04	4.70 ± 0.52	
Tomato Rupali	5.2	4.19± 0.64	2.99 ± 0.81	1.20 ± 0.30	2.42 ± 0.39	0.59 ± 0.10	0.49 ± 0.10	
Water melon								127, 148
Baby sugar	4.7	12.60± 0.61	6.92 ± 0.39	2.41 ± 0.30	5.90 ± 0.23	0.47 ± 0.02	7.18 ± 1.20	
Local								
Min.	—	10.90	7.30	1.80	5.23	0.48	—	
Max.	—	15.00	8.70	2.60	6.98	0.47	—	
Av.	—	12.80	8.10	2.20	6.11	0.48	—	

Table 2.5 Spatial dimensions, size and sphericity of spices

Seed/Variety	Moisture content, % (db)	Length, mm	Width /dia, mm	Thickness, mm	Size, mm	Shericity	Proejcted area, mm^2	Reference
1.	2.	3.	4.	5.	6.	7.	8.	9.
Aniseed (local)								49
Coarse	10.8	4.05–7.30	1.25–2.60	0.95–1.55	1.86–3.01	0.40	25.80	
Fine	9.7	3.20–6.10	0.80–1.45	0.65–1.10	1.30–2.15	0.35	11.90	
Coriander seed								86
Local	10.4	4.90–6.10	2.40–3.55	—	3.30–4.20	0.69	31.50	
Cumin seed								172
Local	7.6	4.10–5.60	0.95–1.55	0.85–1.30	1.49–2.24	0.40	16.90	
Fenugreek seed								172
Local	8.9	3.20–4.90	1.60–2.85	1.35–2.50	1.90–3.27	0.72	26.8	
Turmeric rhyzome								50
Sangali	12.5	23.0–58.0	9.0–21.0	5.0–18.0	10.0–24.0	0.43	—	

CHAPTER III

GRAVIMETRIC PROPERTIES

A knowledge of density, specific gravity and porosity are important in design and analysis of separation, handling, drying, processing, storage and transport equipment and systems. Bulk density decides the capacity of the storage structures, hoppers or transport vehicles body and resulting loads which must be taken into consideration in the design of their components. Specific gravity is a widely used criteria of separation of food materials. Porosity of the solid mass governs the resistance to air flow in a dryer and dictates the thickness of the layers which can be dried safely and the type of blower needed.

Thousand grain weight can be determined using the method described in Indian Standard IS:4333 (Part IV) - 1968. The method is as follows:

1. Determination on 'As - Is' basis :

Take at random an amount of approximately 500 grains from the sample. Sort out the whole grains and weigh. Subsequently, count the whole grains.

2. Determination on dry basis :

If the weight of 1,000 grains is to be referred on dry basis, proceed as above and also determine the moisture content of the whole grains in a separate sample.

Calculation :

The weight of 1,000 grains on 'as-is' basis = $\dfrac{a \times 1{,}000}{b}$

Where,

a = weight of the whole grains, g and

b = number of whole grains in the sample weighed.

Weight of 1,000 grains on dry basis = $\dfrac{A \times (100-B)}{100}$

Where,

A = weight of 1000 grains on 'as-is' basis, g and

B = moisture content, expressed as per centage.

Bulk density can be determined with the help of Indian Standard IS:4333 Part-III-1967. This standard prescribes the method for determining bulk density. Size of the test sample shall be 500 g.

Procedure

1. Fill the pan and hold it over the kettle in such a way that the opening of the pan is above the center of kettle and pouring occurs from a height of about 150mm above the kettle (Fig.3.1). Pour the grain in to the kettle in a regular slow stream.
2. Place the stroker (Fig. 3.1) on the edge of the kettle lightly without jarring the kettle. Hold the stroker on the kettle with the side of the stroker in vertical position. Stroke the grain from the kettle with three full length zig-zag motions of the stroker. Weigh the grain in the kettle on the balance.

Volume can be measured using Air Comparison Pycnometer (Mohsenin, 1980). The Pycnometer (Fig. 3.2) is a commercially available instrument for volume measurement. The apparatus (Fig. 3.2) consists basically of two chambers and two pistons, a valve connecting the two chambers, a differential pressure indicator, and a digital counter calibrated for readings in cm^3. This instrument measures the true volume of a sample. For measurement of apparent volume, i.e., the volume of a sample enclosed by its outer surface plus the volume of its open pores, it is recommended to fill the pores first by immersing the sample in molten wax bath. It works on the principle of pressure differential. The volume of sample can be measured by calibrated scale.

Procedure

1. Close perge valve and open coupling valve.
2. Rotate hand wheels to counter clockwise extreme.
3. Turn measuring hand wheel clockwise until starting number is set on the counter.
4. Place sample in cup. Insert cup in the compartment. Lock sample cup in place by pressing clamp handle down firmly. Wait 15 sec., then close the coupling valve.
5. Turn both handle wheels simultaneously or alternately until reference hand wheel rests against stop. Keep pointer on scale during this process. Wait 10 sec., then bring pointer to null point with measuring hand wheel.
6. Open coupling valve. Read sample volume on counter directly in cm^3.
7. Turn both hand wheels counter clockwise to rest against stop. Remove sample cup.

Volume and ***Specific gravity*** can also be determined by using a general purpose reagent (toluene rectified) with the help of measuring cylinder and using following equation:

$$\text{Volume} = \frac{\text{Weight of displaced liquid}}{\text{Weight density of liquid}} \qquad \ldots (3.1)$$

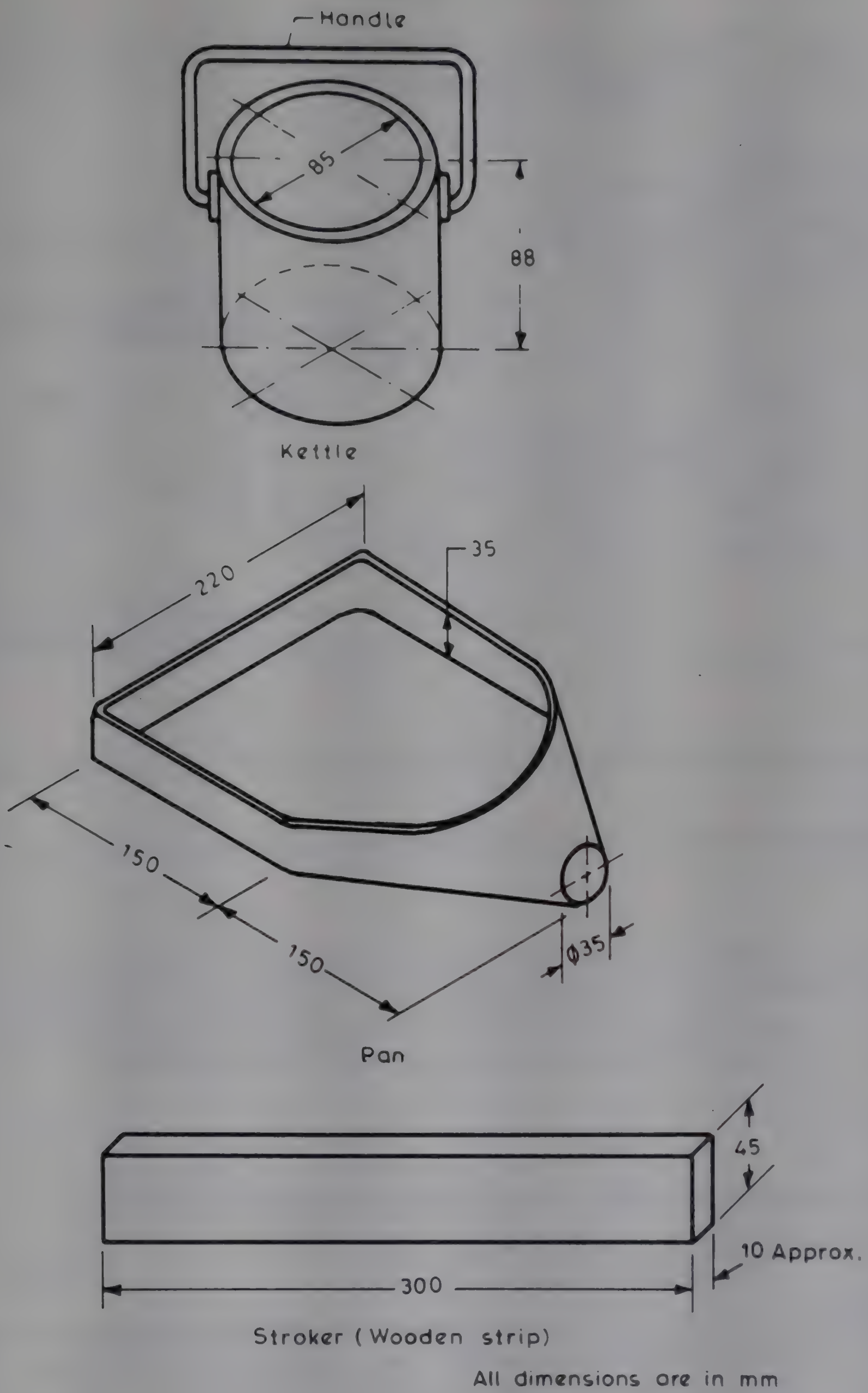


Fig. 3.1. Apparatus for determination of bulk density of grain

$$\text{Specific gravity} = \frac{\text{Weight in air} \times \text{sp. gravity of liquid}}{\text{Weight of displaced liquid}} \qquad \ldots (3.2)$$

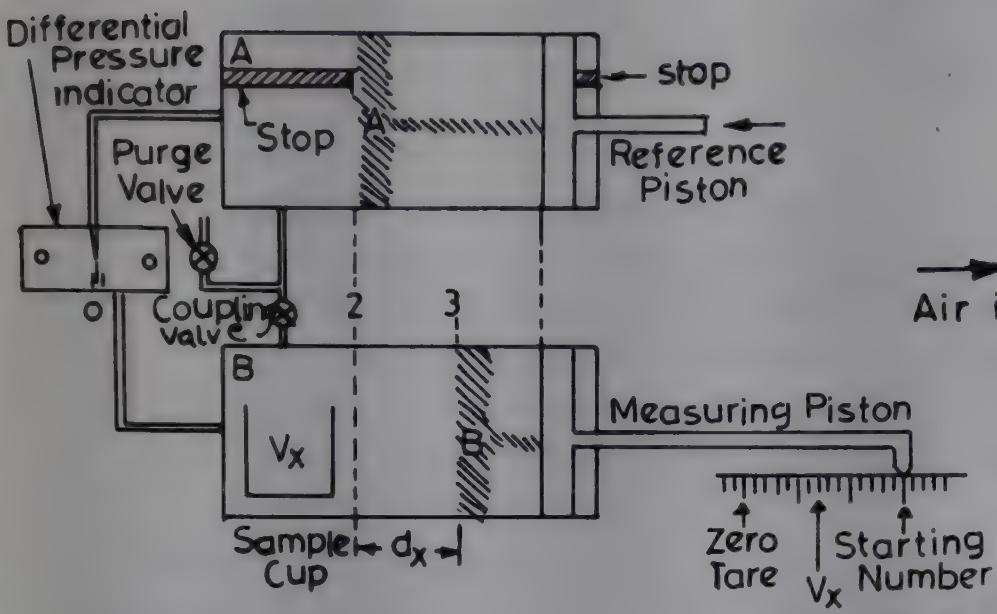


Fig. 3.2. Comparison Pycnometer

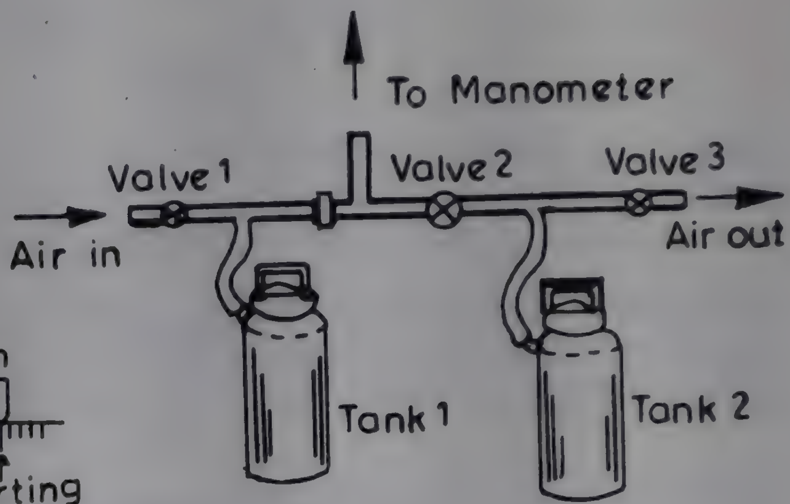


Fig. 3.2. Apparatus for determination of porosity of granular materials (Day, 1964)

Porosity

The per cent voids of an unconsolidated mass of materials in terms of volume can be defined as *porosity.*

Day (1964) has given a simple method for determination of porosity which is illustrated in Fig. 3.3.

Procedure

With the material in tank 2, valve 2 is closed and air is supplied to tank 1 (Fig. 3.3). When suitable manometer displacement is achieved, valve 1 is closed and after the manometer has come to equilibrium, pressure P_1 is read. Now, valve 3 is closed and valve 2 is opened and the pressure P_3 is read. By using the following formula porosity can be calculated:

$$\text{Porosity} = \frac{P_1 - P_3}{P_3} \qquad \ldots (3.3)$$

The porosity can also be determined indirectly using the following definition :

$$\text{Porosity} = \frac{(\textit{Specific gravity} - \textit{Bulk density}) \times 100}{\textit{Specific gravity}} \qquad \ldots (3.4)$$

Various research workers have carriedout studies on the gravimetric properties for cereals (corn, finger millet, paddy, pearl millet, prosomillet, rice, sorghum and wheat); pulses (Bengal gram, black gram, green gram, horse gram, lentil and pigeon pea); oilseeds (castor, groundnut, linseed, mustard, niger seed, safflower, soybean and sunflower); fruit/vegetable seeds (brinjal, long melon, musk melon, peach, pomegranate, pumpkin, summer melon, tomato and water melon) and spices (aniseed, coriander seed, cumin seed, fenugreek seed and turmeric rhyzome) for Indian varieties and jaggery (gur) at different moisture contents. Some of these properties such as, 1000 grain weight, bulk density, specific gravity, volume of a single grain and porosity are listed in the Tables 3.1–3.5.

Table 3.1 : Gravimetric properties of cereal grains

Grain/Variety	Moisture content, % (db)	1000 grain Wt., g	Bulk density, g/cm^3	Specific gravity	Volume of single grain, mm^3	Porosity, %	Reference
1.	2.	3.	4.	5.	6.	7.	8.
Corn							16
Ganga—5	< 10.0	—	0.836	1.41	—	—	
	10.0— 19.9	—	0.833	1.39	—	—	
	20.0 — 29.9	—	0.747	1.31	—	—	
	30.0—39.9	—	0.740	1.30	—	—	
	40.0—50.0	—	0.740	1.30	—	—	
Kisan composite	—	349.7	—	1.22	286.0	—	
	—	282.3	—	1.23	252.3	—	
Local	< 10.0	—	0.820	1.39	—	—	
	10.0—19.9	—	0.812	1.35	—	—	
	20.0—29.9	—	0.792	1.32	—	—	
	30.0—39.9	—	0.740	1.26	—	—	
	40.0 —50.0	—	0.740	1.23	—	—	
MLU—5	7.6	—	0.684	—	—	30.08	
	22.5	—	0.609	—	—	37.16	
	28.4	—	0.601	—	—	36.12	
	20.0 —29.9	—	0.792	1.32	—	—	
	30.0 —39.9	—	0.740	1.26	—	—	
	40.0 —50.0	—	0.740	1.23	—	—	
Vijay composite	< 10.0	—	0.835	1.37	—	—	
	10.0 —19.9	—	0.824	1.37	—	—	
	20.0 —29.9	—	0.750	1.34	—	—	
	30.0 —39.9	—	0.745	1.31	—	—	
	40.0—50.0	—	0.743	1.30	—	—	
Finger millet							16
Co—11	9.8	—	0.706	—	—	45.10	
	19.8	—	0.668	—	—	35.08	
	32.5	—	0.645	—	—	42.44	
Paddy							10,173
ADT—3	10.1	—	0.593	—	—	—	
ADT—4	11.3	—	0.684	—	—	—	
ADT—10	11.3	—	0.545	—	—	—	
ADT—11	11.4	—	0.594	—	—	—	

Table Contd.....

1.	2.	3.	4.	5.	6.	7.	8.
ADT—16	10.4	—	0.559	—	—	—	
ADT—20	10.8	—	0.622	—	—	—	
ADT—22	11.7	—	0.565	—	—	—	
ADT—27	8.5—24.0	—	0.580	1.24	—	51.25	
	10.4	—	0.580	—	—	—	
ADT—28	10.8	—	0.606	—	—	—	
ADT—31	9.6	—	0.614	—	—	—	
Akkular	18.0	—	0.569	1.47	—	61.0	
	19.8	—	0.575	1.43	—	56.0	
	22.8	—	0.580	1.40	—	58.0	
	24.1	—	0.587	1.35	—	56.0	
Annapoorna	9.8	—	0.588	—	—	—	
Anupama	10.6	—	0.578	—	—	—	
ASD—1	9.9	—	0.575	—	—	—	
ASD—5	10.5	—	0.527	—	—	—	
ASD—8	9.9	—	0.574	—	—	—	
ASD—10	12.5	—	0.544	—	—	—	
ASD—11	10.8	—	0.548	—	—	—	
Bala	10.7	—	0.614	—	—	—	
BAM—3	10.4	—	0.569	—	—	—	
Basmathi	13.6	—	0.530	—	—	—	
Basumathi	—	—	0.499	—	—	—	
BC, 11—6—3	12.1	—	0.551	—	—	—	
Bhavani	10.2	—	0.595	—	—	—	
Cauvery	12.0	22.28	0.580	1.38	—	57.97	
	14.0	22.79	0.580	1.38	—	57.97	
	16.0	23.02	0.580	1.39	—	58.27	
	18.0	23.21	0.590	1.39	—	57.55	
	20.0	23.73	0.600	1.40	—	57.14	
CH—2	11.1	—	0.586	—	—	—	
CH, SO—16	11.2	—	0.566	—	—	—	
Co—1	11.3	—	0.565	—	—	—	
Co—2	11.2	—	0.563	—	—	—	
Co—4	10.2	—	0.547	—	—	—	
Co—7	11.9	—	0.548	—	—	—	
Co—8	9.8	—	0.528	—	—	—	

Table Contd.....

1.	2.	3.	4.	5.	6.	7.	8.
Co—10	9.9	—	0.608	—	—	—	
Co—13	9.8	—	0.535	—	—	—	
Co—16	11.1	—	0.582	—	—	—	
Co—18	9.9	—	0.576	—	—	—	
Co—19	10.7	—	0.599	—	—	—	
Co—25	8.5–24.0	—	0.600	1.25	—	31.63	
	10.0	—	0.570	—	—	—	
Co—26	10.8	—	0.575	—	—	—	
Co—29	9.7	—	0.578	—	—	—	
Co—30	11.0	—	0.540	—	—	—	
Co—32	11.5	—	0.532	—	—	—	
Co—33	9.2	—	0.590	1.25	—	49.70	
	10.6	—	0.592	—	—	—	
Co—34	10.4	—	0.575	—	—	—	
Co—35	9.9	—	0.589	—	—	—	
Co—36	10.4	—	0.594	—	—	—	
Co—37	10.7	—	0.613	—	—	—	
CR—12—170	11.7	—	0.542	—	—	—	
Desal	10.1	—	0.590	—	—	—	
GEB—24	10.7	—	0.603	—	—	—	
Gettu	10.7	—	0.578	—	—	—	
IET—1039	11.1	—	0.570	—	—	—	
IET—2222	10.3	—	0.577	—	—	—	
IET—2585	11.5	—	0.597	—	—	—	
IR—5	9.9	—	0.567	—	—	—	
	15.9	—	0.572	1.23	—	—	
IR—8	10.1	—	0.555	—	—	—	
	14.2	—	0.573	—	—	—	
IR—20	9.9	—	0.617	—	—	—	
	8.5–23.0	—	0.570	1.22	—	53.53	
IR—24	10.0	—	0.550	—	—	—	
IR—26	10.9	—	0.547	—	—	—	
Jagannath	10.0	—	0.570	—	—	—	
	16.1	—	0.605	1.38	—	56.16	
	18.1	—	0.610	1.37	—	55.47	
	21.3	—	0.617	1.36	—	54.60	

Table Contd.....

1.	2.	3.	4.	5.	6.	7.	8.
	23.8	—	0.624	1.34	—	53.47	
	25.8	—	0.630	1.33	—	52.45	
Jaha	—	14.57	0.600	1.18	—	49.68	
Jaya	8.5—10.5	—	0.590	1.24	—	46.85	
	9.7	—	0.579	—	—	—	
	12.0	27.09	0.540	1.33	—	59.39	
	14.0	27.70	0.550	1.33	—	58.64	
	14.8	—	0.523	1.15	—	28.30	
	16.0	27.74	0.570	1.34	—	57.46	
	16.4	—	0.542	1.50	—	63.80	
	18.0	—	0.544	1.48	—	63.20	
	20.0	29.52	0.580	1.34	—	56.71	
	21.1	—	0.547	1.44	—	62.00	
	22.6	—	0.550	1.42	—	61.20	
	24.8	—	0.554	1.41	—	60.70	
Kakitya	9.9	—	0.588	—	—	—	
Kanaagi	11.0	—	0.612	—	—	—	
Karikala	9.8	—	0.598	—	—	—	
Krishna	9.7	—	0.564	—	—	—	
Masori	13.6	—	0.590	1.45	—	59.00	
	17.0	—	0.590	1.42	—	57.00	
	20.9	—	0.603	1.40	—	56.00	
	23.9	—	0.609	1.37	—	55.00	
	27.4	—	0.614	1.35	—	54.00	
Monoharsali	—	28.30	0.600	1.22	—	51.17	
Mozhikarupper	9.9	—	0.504	—	—	—	
N-12	12.0	19.39	0.550	1.33	—	58.64	
	14.0	19.58	0.560	1.33	—	57.89	
	16.0	19.95	0.570	1.33	—	57.14	
	18.0	20.79	0.580	1.34	—	54.71	
	20.0	20.99	0.590	1.34	—	55.97	
Padma	9.9	—	0.563	—	—	—	
Pankaj	10.0	—	0.588	—	—	—	
Patnai—23	14.6	—	0.455	1.20	—	—	
Patnai local	14.0	—	0.576	1.24	—	—	
Pennai	9.8	—	0.594	—	—	—	
PLR—1	10.9	—	0.586	—	—	—	
PLR—2	10.9	—	0.592	—	—	—	

Table Contd.....

1.	2.	3.	4.	5.	6.	7.	8.
Prasad bhog	—	18.66	0.580	1.24	—	53.44	
PTB—10	10.8	—	0.598	—	—	—	
PTB—15	11.4	—	0.556	—	—	—	
PVR—1	10.2	—	0.595	—	—	—	
Ratna	10.8	—	0.551	—	—	—	
	12.0	19.86	0.500	1.44	—	65.27	
	14.0	20.14	0.500	1.44	—	65.27	
	16.0	20.54	0.500	1.46	—	65.51	
	18.0	20.55	0.510	1.46	—	65.06	
	20.0	20.74	0.520	1.46	—	64.38	
Rohini	9.7	—	0.597	—	—	—	
RP—4—2	11.3	—	0.549	—	—	—	
RP—4—14	11.4	—	0.532	--	—	—	
RP—172-2	11.5	—	0.577	—	—	—	
RP—176—5	12.6	—	0.590	—	—	—	
Sabarmathi	9.8	—	0.573	—	—	—	
Saket—4	12.0	19.55	0.550	1.37	—	59.85	
	14.0	20.54	0.550	1.38	—	60.14	
	16.0	20.81	0.560	1.38	—	59.42	
	18.0	20.91	0.570	1.38	—	58.69	
	20.0	21.28	0.590	1.39	—	57.55	
Sona	9.9	—	0.535	—	—	—	
Thellhamsa	10.2	—	0.554	—	—	—	
Thillain ayagam (Perururni)	11.6	—	0.581	—	—	—	
Thillainaya gan (Paramakudi)	10.2	—	0.578	—	—	—	
TKM—4	9.5	—	0.546	—	—	—	
TKM—5	9.8	—	0.591	—	—	—	
TKM—6	8.5—24.0	—	0.610	1.29	—	53.21	
	9.9	—	0.561	—	—	—	
TNR-2	11.7	—	0.534	—	—	—	
Triveni	9.8	—	0.622	—	—	—	
Type—3	12.0	18.55	0.530	1.32	—	59.84	
	14.0	18.74	0.540	1.32	—	59.09	
	16.0	19.08	0.550	1.33	—	59.09	
	18.0	19.09	0.570	1.34	—	57.46	
	20.0	19.86	0.580	1.34	—	56.71	
Vijaya	10.5	—	0.601	—	—	—	
6–17	15.2	—	0.408	1.26	—	67.80	

Table Contd.....

1.	2.	3.	4.	5.	6.	7.	8.
	17.2	—	0.411	1.25	—	67.10	
	19.3	—	0.417	1.22	—	65.80	
	25.8	—	0.429	1.20	—	64.20	
	28.7	—	0.435	1.19	—	63.40	
633	12.5	—	0.610	—	—	—	
658	11.2	—	0.578	—	—	—	
688	11.5	—	0.570	—	—	—	
4611	11.3	—	0.585	—	—	—	
4614	12.7	—	0.619	—	—	—	
6464	12.3	—	0.600	—	—	—	
6534	11.9	—	0.724	—	—	—	
6543	11.8	—	0.608	—	—	—	
6547	12.4	—	0.604	—	—	—	
7711	11.6	—	0.573	—	—	—	
8111	12.0	—	0.642	—	—	—	
Pearl millet							36
Co—6	8.9	—	0.795	—	—	42.44	
	25.1	—	0.701	—	—	30.85	
	30.0	—	—	—	—	33.15	
HB—1	8.0	—	0.775	1.28	—	39.50	
	11.0	—	0.767	1.26	—	41.00	
	14.0	—	0.756	1.24	—	42.50	
	17.0	—	0.745	1.24	—	42.20	
	20.0	—	0.737	1.23	—	43.00	
Prosomillet (common millet/Baragu)							18
BR—7	—	6.0	0.744	—	—	—	
CO—1	—	6.5	0.740	—	—	—	
CO—2	—	6.3	0.720	—	—	—	
CO—3	—	5.0	0.630	—	—	—	
CO—4	—	7.2	0.742	—	—	—	
C2PM—13	—	4.5	0.680	—	—	—	
K—1	—	9.0	0.756	—	—	—	
K—2	—	8.0	0.768	—	—	—	
MS—1685	—	7.0	0.730	—	—	—	
PC—1	—	4.7	0.720	—	—	—	
PC—2	—	5.5	0.712	—	—	—	
PC—3	—	5.0	0.630	—	—	—	
Raum—5	—	6.6	0.732	—	—	—	
Raum—7	—	5.5	0.714	—	—	—	
Raum—9	—	4.0	0.700	—	—	—	
Raum—10	—	4.5	0.640	—	—	—	
Raum—11	—	3.5	0.660	—	—	—	

Table Contd.....

1.	2.	3.	4.	5.	6.	7.	8.
Rice(brown)							33
Jaha	—	11.54	0.790	1.39	—	43.53	
Monaharsali	—	22.33	0.820	1.39	—	41.49	
Prasadbhog	—	14.54	0.800	1.39	—	42.96	
Rice(milled)							33
ASM—25	12.5	32.6	0.532	1.11	—	52.20	
ASM—44	12.5	27.2	0.568	1.15	—	50.80	
ASM—51	12.5	25.9	0.526	1.14	—	53.90	
Baok	12.5	29.9	0.422	1.22	—	65.30	
Beak Ganggas	12.5	25.0	0.472	1.19	—	60.10	
Benong—13	12.5	24.7	0.500	1.23	—	59.30	
CR—28—25	—	18.0	—	1.09	16.2	—	
IR—8—288—3	—	26.8	—	1.08	25.9	—	
Jaha	—	11.40	0.800	1.41	–	42.26	
Jenugudu	12.5	16.0	0.563	1.22	—	53.90	
Monoharsali	—	21.65	0.830	1.41	—	40.92	
MR—44	12.5	23.3	0.551	1.23	—	55.00	
Prasadbhog	—	14.23	0.810	1.41	—	42.41	
Purple Puttu	12.5	27.1	0.509	1.08	—	52.90	
Sukhanandi	12.5	23.4	0.580	1.22	—	52.60	
S—701	12.5	19.7	0.897	1.24	—	51.40	
S—705	12.5	22.2	0.560	1.23	—	54.40	
Taichung—65	12.5	25.7	0.611	1.19	—	48.60	
Taichung (N) 1	12.5	26.0	0.607	1.22	—	50.20	
Taiwan—3	12.5	25.2	0.606	1.18	—	48.60	
White Puttu	12.5	28.0	0.483	1.16	—	58.20	
Sorghum							138,147
Co-22	10.5	26.0	0.727	1.27	—	—	
Co-23	13.4	25.9	0.761	1.25	—	—	
CSH-5	11.3	—	0.754	1.28	—	—	
	12.0	—	0.787	1.35	—	41.49	
	16.0	—	0.779	1.33	—	41.60	
	20.0	—	0.767	1.32	—	41.91	
	24.0	—	0.746	1.31	—	43.11	
CSH-SR	12.0	—	0.746	1.28	—	41.81	
	16.0	—	0.735	1.27	—	42.30	
	20.0	—	0.725	1.27	—	42.71	
	24.0	—	0.690	1.25	—	44.78	

Table Contd.....

1.	2.	3.	4.	5.	6.	7.	8.
HB-MSCK-60-IS-84	—	35.0	—	1.29	27.3	—	
Local	8.4	—	0.669	—	—	41.76	
	12.6	—	0.750	1.27	—	—	
	20.6	26.0	0.620	—	—	31.44	
	29.1	—	0.570	—	—	42.08	
	—	34.0	—	1.22	28.3	—	
M-35-1	12.0	—	0.795	1.26	—	37.85	
	16.0	—	0.766	1.25	—	38.65	
	20.0	—	0.751	1.23	—	39.19	
	24.0	—	0.737	1.22	—	39.53	
SPH-202	12.0	—	0.808	1.34	—	39.52	
	16.0	—	0.791	1.32	—	40.18	
	20.0	—	0.770	1.31	—	41.35	
	24.0	—	0.758	1.30	—	41.83	
SPU-86	12.0	—	0.798	1.31	—	39.23	
	16.0	—	0.785	1.30	—	39.67	
	20.0	—	0.774	1.29	—	40.08	
	24.0	—	0.752	1.28	—	41.27	
Wheat							41,76
C-306	—	49.70	0.800	—	—	—	
CPAN-1676	—	43.20	0.764	—	—	—	
HD-2189	7.7	—	0.719	—	—	41.31	
	20.9	—	0.626	—	—	39.09	
	30.4	—	0.611	—	—	35.33	
HD—2204	—	48.60	0.772	—	—	—	
HD—2281	—	49.30	0.731	—	—	—	
HD—2285	—	53.20	0.781	—	—	—	
HS—86	—	50.00	0.746	—	—	—	
Malviya—12	—	48.20	0.740	—	—	—	
NP—720	—	48.7	—	1.38	35.3	—	
PB—593	—	51.5	—	1.39	37.2	—	
RR—21	9.1	—	0.830	1.34	—	40.20	
	9.2	—	0.810	1.40	—	41.95	
	11.3	—	0.820	1.37	—	40.70	
	13.3	—	0.810	1.37	—	46.90	
	18.3	—	0.780	1.47	—	41.31	
Sonalika	—	42.70	0.773	—	—	—	
UP—115	—	46.70	0.756	—	—	—	
UP—262	—	52.00	0.770	—	—	—	
UP—368	—	48.20	0.764	—	—	—	
UP—2003	—	46.80	0.737	—	—	—	
VL—421	—	40.30	0.757	—	—	—	
WH—147	6.7	40.90	—	1.41	—	—	

Table 3.1.1 : Linear regression equation of bulk density, kg/m^3 (Y) and moisture content, %, wb. (X)

Grain/Variety	Regression equation	Correlation coefficient	Reference
Finger millet			
CO—10	$Y = 826.1 - 3.9\,X$	0.99	177
Foxtail millet			
Local	$Y = 815.5 - 8.6\,X$	0.95	
Kodo millet			
Local	$Y = 883.7 - 9.2\,X$	0.90	
Little millet			
Local	$Y = 849.6 - 12.7\,X$	0.97	
Pearlmillet			
Km—2	$Y = 854.5 - 4.2\,X$	0.98	
Sorghum			
CO—18	$Y = 967.9 - 9.9\,X$	0.99	

Table 3.2 : Gravimetric properties of pulses

Grain/Variety	Moisture content, % (db)	1000 grain wt.,g	Bulk density, g/cm^3	Specific gravity	Volume of single grain, mm^3	Porosity, %	Reference
1.	2.	3.	4.	5.	6.	7.	8.
Bengal gram (chickpea)							41,52
BR—77	—	206.20	—	1.28	161.7	—	
C—235	7.5	—	0.783	—	107.0	—	
	8.0	142.40	—	1.36	—	—	
	13.6	—	0.811	—	114.0	—	
	21.9	—	0.794	—	135.9	—	
	31.6	—	0.756	—	169.8	—	
CS—24	7.5	147.30	0.755	—	102.1	—	
	13.6	155.80	0.763	—	109.2	—	
	21.9	167.20	0.752	—	119.6	—	
	31.6	180.30	0.714	—	136.8	—	
JG—74	14.9	179.390	0.750	1.43	—	—	
L—550	14.9	243.80	0.800	1.25	—	—	
Radhey	7.5	—	0.753	—	162.0	—	
	13.6	—	0.760	—	166.0	—	
	21.9	—	0.748	—	172.6	—	
	31.6	—	0.723	—	186.2	—	
Ujjain—21	14.9	175.15	0.670	1.32	—	—	
Black gram							52,173
DU—1	—	48.35	0.720	1.43	—	—	
DU—2	—	45.13	0.780	1.15	—	—	
DU—3	—	47.01	0.800	1.39	—	—	
DU—4	—	46.75	0.790	1.33	—	—	
JU—77—41	—	35.13	0.800	1.12	—	—	
JU—78—3	—	45.19	0.780	1.02	—	—	
JU—78—27	—	40.00	0.800	1.25	—	—	
Khargone—3	—	47.00	0.690	1.28	—	—	
N—55	—	35.30	0.600	1.29	—	—	
Pant 4—30	—	40.32	0.810	1.03	—	—	
PDU—1	—	45.16	0.740	1.43	—	—	
PDU—3	—	40.31	0.800	1.28	—	—	
PU—26	—	34.50	0.710	1.34	—	—	
PU—30	—	34.70	0.670	1.32	—	—	
RU—2	—	39.75	0.840	1.09	—	—	
Sardomagh	—	42.31	0.770	1.19	—	—	

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.
T—9	—	35.24	0.790	1.16	—	—	
	7.5	38.10	0.879	—	24.2	—	
	13.6	40.80	0.927	—	25.3	—	
	21.9	43.60	0.871	—	27.0	—	
	31.6	47.40	0.763	—	30.3	—	
727	—	50.50	—	1.34	38.6	—	
UG—201	—	39.70	0.820	1.11	—	—	
UG—218	—	43.31	0.780	1.28	—	—	
UG—236	—	45.36	0.800	1.06	—	—	
UH—28	—	39.80	0.800	1.24	—	—	
UH—87	—	40.25	0.830	1.33	—	—	
UH—80—4	—	40.00	0.790	1.25	—	—	
Cowpea							173
T—2	—	152.30	—	1.19	128.3	—	
Greengram							41,52,143
HB—45	—	30.00	—	1.55	19.5	—	
J—45	—	30.66	0.670	1.45	—	—	
K—851	—	45.00	0.750	1.05	—	—	
Kopargaon	—	52.67	0.580	1.38	—	—	
MH—87—7	—	35.00	0.650	1.11	—	—	
MH—309	—	40.00	0.720	1.18	—	—	
Pant Mung—2	—	36.12	0.770	1.07	—	—	
PB	7.5	36.70	0.759	—	28.5	—	
	13.6	39.30	0.764	—	33.0	—	
	21.9	41.80	0.748	—	37.3	—	
	31.6	45.30	0.715	—	40.6	—	
PS—16	—	35.25	0.770	1.18	—	—	
Pusa—Baisaki	—	36.33	0.560	1.58	—	—	
Pusa—105	—	35.30	0.740	1.04	—	—	
Rahuri	—	35.20	0.700	1.03	—	—	
UPM—82—4	—	35.18	0.730	1.06	—	—	
UPM—83—10	—	33.10	0.760	1.17	—	—	
11—395	—	39.15	0.690	1.25	—	—	
Horsegram							41
Local	—	32.10	0.829	1.33	—	—	
Lentil							52
L—9—12	7.5	17.8	0.765	—	13.4	—	
	13.6	18.9	0.753	—	14.4	—	
	21.9	20.2	0.734	—	15.3	—	
	31.6	21.8	0.711	—	15.9	—	

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.
Pea							41,52
Arcle	7.5	—	0.630	—	131.6	—	
	13.6	—	0.632	—	144.6	—	
	21.9	—	0.622	—	155.2	—	
	31.6	—	0.592	—	160.4	—	
Banniville	—	239.40	—	1.13	213.6	—	
VRS—6115	—	210.40	—	1.37	160.8	—	
Pigeon pea							52,173
ICPL—1	13.6	—	0.850	1.14	—	—	
ICPL—6	13.6	—	0.770	1.02	—	—	
ICPL—87	13.6	—	0.760	1.05	—	—	
ICPL—131	13.6	—	0.780	1.15	—	—	
ICPL—138	13.6	—	0.760	1.13	—	—	
ICPL—211	13.6	—	0.800	1.14	—	—	
ICPL—227	13.6	—	0.740	1.07	—	—	
ICPL—270	13.6	—	0.750	1.03	—	—	
ICPL—332	13.6	—	0.830	1.13	—	—	
ICPL—333	13.6	—	0.800	1.08	—	—	
ICPL—7035	13.6	—	0.770	1.17	—	—	
ICPL—84060	13.6	—	0.810	1.15	—	—	
JA—3	7.5	90.00	0.758	—	67.1	—	
	7.9	90.50	—	1.34	—	—	
	13.6	94.30	0.734	—	70.8	—	
	21.9	102.30	0.689	—	87.8	—	
	31.6	109.60	0.628	—	92.7	—	
K—11	—	120.20	—	1.33	90.9	—	
Local	9.2	—	0.820	1.33	—	38.5	
	10.8	—	0.810	1.33	—	39.0	
	14.1	—	0.810	1.33	—	39.5	
	18.9	—	0.810	1.33	—	40.0	
UPAS—120	12.4	—	0.948	1.36	—	37.5	
	13.2	—	0.845	1.35	—	37.4	
	14.9	—	0.943	1.35	—	37.5	
	16.5	—	0.911	1.34	—	37.5	
	19.3	—	0.938	1.34	—	37.6	
	20.2	—	0.933	1.34	—	37.8	
	26.6	—	0.925	1.34	—	39.3	

Table 3.3 : Gravimetric properties of oilseeds

Grain/Variety	Moisture content, % (db)	1000 grain wt, g	Bulk density, g/cm^3	Specific gravity	Volume of single seed, mm^3	Porosity, %	Reference
1.	2.	3.	4.	5.	6.	7.	8.
Castor							51,54
NPH—1	7.5	—	0.568	—	187.10	—	
	13.6	—	0.571	—	189.70	—	
	21.9	—	0.569	—	192.10	—	
	31.6	—	0.566	—	196.70	—	
Local							
Small	5.4	178.0	0.582	0.89	225.00	34.3	
Medium	5.3	566.5	0.457	0.85	666.00	46.3	
Large	4.9	686.7	0.475	0.71	900.00	33.0	
Groundnut (kernel)							41,53
G—11	7.5	—	0.593	—	364.30	—	
	13.6	—	0.604	—	374.20	—	
	21.9	—	0.572	—	403.20	—	
	31.6	—	0.554	—	441.70	—	
RS—1	—	507.3	—	0.93	545.00	—	
TG—3	7.5	—	0.604	—	236.80	—	
	13.6	—	0.614	—	257.30	—	
	21.9	—	0.593	—	321.20	—	
	31.6	—	0.584	—	443.40	—	
Groundnut (pods)							10,75,137
GAUG-1	5.3	–	0.321	0.66	–	69.9	
	13.6	–	0.326	0.68	–	67.8	
	20.5	–	0.342	0.71	–	66.2	
	28.2	–	0.356	0.79	–	65.4	
GAUG-10	5.3	–	0.238	0.49	–	76.8	
	13.6	–	0.238	0.52	–	74.8	
	20.5	–	0.246	0.53	–	73.6	
	28.2	–	0.266	0.57	–	73.2	
GG-2	5.3	–	0.287	0.59	–	70.9	
	13.6	–	0.297	0.62	–	68.4	
	20.5	–	0.303	0.63	–	66.7	
	28.2	–	0.328	0.71	–	66.0	
GG-11	5.3	–	0.221	0.45	–	77.0	
	13.6	–	0.224	0.45	–	75.4	
	20.5	–	0.238	0.49	–	74.4	
	28.2	–	0.247	0.53	–	73.6	

Table Contd...

1.	2.	3.	4.	5.	6.	7.	8.
M-13	5.3	–	0.211	0.43	–	78.1	
	13.6	–	0.219	0.47	–	76.3	
	20.5	–	0.229	0.48	–	75.3	
	28.2	–	0.243	0.50	–	75.0	
JL—24							
Single kernel ellipsoid	10.3	—	—	0.61	—	—	
Double kernel ellipsoid	10.3	—	—	0.56	—	—	
Paired ellipsoid	10.3	—	—	0.53	—	—	
Cassinoids	10.3	—	—	0.55	—	—	
Triple kernel ellipsoid	10.3	—	—	0.55	—	—	
Pol.1	—	—	0.308	—	—	—	
TMV—1	—	—	0.317	—	—	—	
TMV—3	—	—	0.274	—	—	—	
TMV—7	—	—	0.281	—	—	—	
Linseed							20
JL—23—01	—	6.50	0.700	1.18	—	40.68	
LC—54	5.4	—	0.732	1.13	—	35.44	
	11.0	—	0.696	1.11	—	37.24	
	16.4	—	0.652	1.10	—	40.61	
	22.3	—	0.588	1.10	—	46.36	
	28.1	—	0.586	1.08	—	45.84	
LC—185	5.4	—	0.718	1.13	—	36.51	
	11.0	—	0.712	1.11	—	35.85	
	16.4	—	0.692	1.11	—	37.43	
	22.3	—	0.642	1.10	—	41.58	
	28.1	—	0.637	1.07	—	40.46	
R—7	7.5	—	0.556	—	7.00	—	
	13.6	—	0.558	—	7.60	—	
	21.9	—	0.555	—	8.10	—	
	31.6	—	0.546	—	8.30	—	
T—59	6.8	9.24	—	1.08	—	—	
Mustard							9
Pusabold	7.5	—	0.564	—	3.70	—	
	8.0	7.10	—	1.13	—	—	
	13.6	—	0.572	—	4.00	—	
	21.9	—	0.567	—	4.30	—	

Table Contd...

1.	2.	3.	4.	5.	6.	7.	8.
	31.6	—	0.556	—	4.70	—	
Niger seed							78
Local	10.1	2.85	—	1.07	—	—	
Safflower							9,78
JSF—1	7.0	74.77	—	1.00	—	—	
	7.5	—	0.624	—	80.32	—	
	13.6	—	0.621	—	84.60	—	
	21.9	—	0.619	—	87.70	—	
	31.6	—	0.604	—	90.00	—	
Soybean							37,173
Ankur	—	107.22	0.950	1.19	—	—	
Bragg	—	148.67	0.970	1.11	—	—	
	9.2	—	0.680	1.20	—	43.40	
	9.4	—	0.810	1.33	—	41.40	
	10.8	—	0.690	1.18	—	41.80	
	13.6	—	0.680	1.18	—	42.20	
	19.6	—	0.670	1.28	—	48.10	
DS—76—1—29	—	101.99	0.990	1.21	—	—	
JS—2	7.5	—	0.684	—	168.80	—	
	13.6	—	0.659	—	179.00	—	
	21.9	—	0.647	—	204.00	—	
	31.6	—	0.624	—	210.70	—	
	—	153.97	0.960	1.10	—	—	
JS—7244	8.7	110.0	0.736	1.22*	91.00	39.50	
	10.4	111.0	0.732	1.19*	93.00	38.80	
	14.6	115.0	0.723	1.17*	98.00	38.40	
	16.4	120.0	0.721	1.17*	103.00	38.20	
	21.8	124.0	0.713	1.14*	109.00	37.60	
	25.0	127.0	0.708	1.12*	113.00	37.00	
JS—75—19	—	121.64	0.880	1.03	—	—	
JS—75—45	—	122.66	0.940	1.38	—	—	
JS—76—205	—	104.20	0.930	1.12	—	—	
JS—76—259	—	110.84	0.960	1.09	—	—	
JS—76—280	—	93.93	0.970	1.10	—	—	
JS—80—21	—	103.27	0.970	1.37	—	—	
Kalituar	—	75.01	0.970	1.15	—	—	
Lee	—	194.70	—	1.15	171.10	—	
Local	6.7	—	0.672	—	—	34.94	
	19.9	—	0.620	—	—	—	

* Kernel density

Table Contd...

1.	2.	3.	4.	5.	6.	7.	8.
	—	—	—	—	—	34.40	
	23.8	—	—	—	—	30.32	
	29.7	—	—	—	—	—	
MACS—75	—	105.49	0.920	1.39	—	—	
N—19	—	100.44	0.980	1.14	—	—	
PK—472	—	123.12	0.980	1.10	—	—	
Punjab—1	—	149.70	—	1.22	131.00	—	
T—49	—	73.02	0.970	1.09	—	—	
Sunflower (head)							113
Morden	—	—	0.085	0.26	1.53×10^5	67.4	
Sunflower (seed)							9,41,113
CO—1	4.3	—	0.311	—	—	58.81	
	19.9	—	0.312	—	—	—	
	25.0	—	0.336	—	—	46.03	
CMS—234A	—	38.64	0.368	0.64	—	—	
GD—1	—	28.64	0.451	0.63	—	—	
KSH—1	—	36.33	0.297	0.64	—	—	
Morden	7.6	—	0.414	—	—	—	
	7.9	—	0.289	0.65	62.00	55.00	
	9.2	42.18	—	—	70.50	—	
	13.6	—	0.422	0.73	76.10	—	
	21.9	—	0.409	—	80.40	—	
	31.6	—	0.384	—	82.23	—	
	—	41.12	0.359	0.61	—	—	
RHA—274	—	27.66	0.412	0.69	—	—	

Table 3.4: Gravimetric properties of fruit and vegetable seeds

Crop/Variety	Moisture content, % (db)	1000 grain wt., g	Bulk density, g/cm^3	Specific gravity	Volume of single seed, mm^3	Porosity, %	Reference
1.	2.	3.	4.	5.	6.	7.	8.
Brinjal							148
Local	3.6	2.3	0.418	0.61	2.15 ± 0.48	31.8	
Gorgon nut (makhana)							
Local	15-60	195-894	0.541-09. 776	1.11-1.25	–	37.60-51.30	70
Long melon							127
Hull	—	—	0.120	—	—	—	
Kernel	—	—	0.480—0.560	—	—	—	
Seed	—	—	0.460	—	—	—	
Musk melon							127
Hull	—	—	0.100—0.120	—	—	—	
Kernel	—	—	0.500—0.540	—	—	—	
Seed	—	—	0.450—0.470	—	—	—	
Peach fruit							173
Local	—	—	—	—	61.58×10^3	—	
Pomegranate							
Seed testa	—	—	0.700	—	—	—	173
Whole seed	—	—	0.530	—	—	—	
Pumpkin							148
Local	10.9	150.8	0.394	0.81	264 .00 ± 56.22	51.5	
Summer melon							148
Local	4.5	37.6	0.446	0.86	36.94± 7.94	51.5	
Tomato							148
Rupali	5.2	2.6	0.454	1.13	8.04 ± 4.03	59.9	
Water melon							127,148
Baby sugar	4.7	104.9	0.474	0.83	107.88 ± 12.57	42.6	
Hull	—	—	0.200	—	—	—	
Kernel	—	—	0.500—0.600	—	—	—	
Seed	—	—	0.460—0.580	—	—	—	

Table 3.5 Gravimetric properties of spices and jaggery

Seed/ Variety	Moisture content, % (db)	1000 grain wt; g	Bulk density, g/cm^3	Specific gravity	Volume of single seed, mm^3	Porosity, %	Reference
1.	2.	3.	4.	5.	6.	7.	8.
Aniseed (local)							49
Coarse	10.8	8.56	0.422	0.98	8.70	56.80	
Fine	9.7	3.48	0.478	1.13	2.30	57.60	
Coriander seed							86
Local	10.4	5.80	0.292	0.65	25.0	54.87	
Cumin seed							172
Local	7.6	3.70	0.420	0.87	3.50	51.95	
Fenugreek seed							
Local	8.9	10.87	0.728	1.38	8.00	41.45	172
Jaggery (gur)							
	4.7	—	1.350*	—	—	—	66
	6.2	—	1.370*	—	—	—	
	7.4	—	1.386*	—	—	—	
	8.4	—	1.404*	—	—	—	
	9.9	—	1.415*	—	—	—	
	11.7	—	1.436*	—	—	—	
	12.4	—	1.438*	—	—	—	
	13.8	—	1.440*	—	—	—	
Turmeric rhyzome							50
Sangali	12.5	1285.0	0.730	1.33	—	45.1	

* True density

CHAPTER - IV

FRICTIONAL PROPERTIES

The need for a knowledge of frictional properties of granular materials such as, seeds and grains on various surfaces has long been recognized by the engineers concerned with rational design of grain bins, silos and other storage structures. Co-efficient of internal friction and expansion characteristics are important in studying consolidation and compressibility of the material and determining methods of compressing and packaging. Angle of repose is important in design of equipment for solid flow and structures for storage of these materials.

Angle of repose: When a granular material is allowed to flow freely from a point into a pile, the angle which the side of the pile makes with horizontal plane is called the angle of repose.

Angle of repose of grains can be determined by the following method (IS:6663, 1972).

Procedure:

1. Place the timber base on a flat and level surface (Fig. 4.1). Fix up the stand along with funnel on the steel base already provided on the timber base so as to keep the funnel outlet 250 mm above the top edge of the container. Place the cylindrical container into a fixed position on the timber base.
2. With the container removed and the funnel outlet gate closed, pour the grain sample until the funnel is full and over flowing. Strike of the heaped cone of grain above the funnel inlet with a ruler.
3. Open the funnel outlet gate fully and allow the grain to fall freely into the measuring container.
4. Care should be taken while filling the container not to move or disturb it, so as to avoid any chance for packing or settling of the grain.
5. Calculate the height of the pile (d_3) (Fig. 4.2) by the formula,

$$d_3 = d_1 - d_2$$

Where, $d_1 = \dfrac{d_{1a} + d_{1b}}{2}$

6. Calculate the tangent of the angle ($\tan \varphi$)

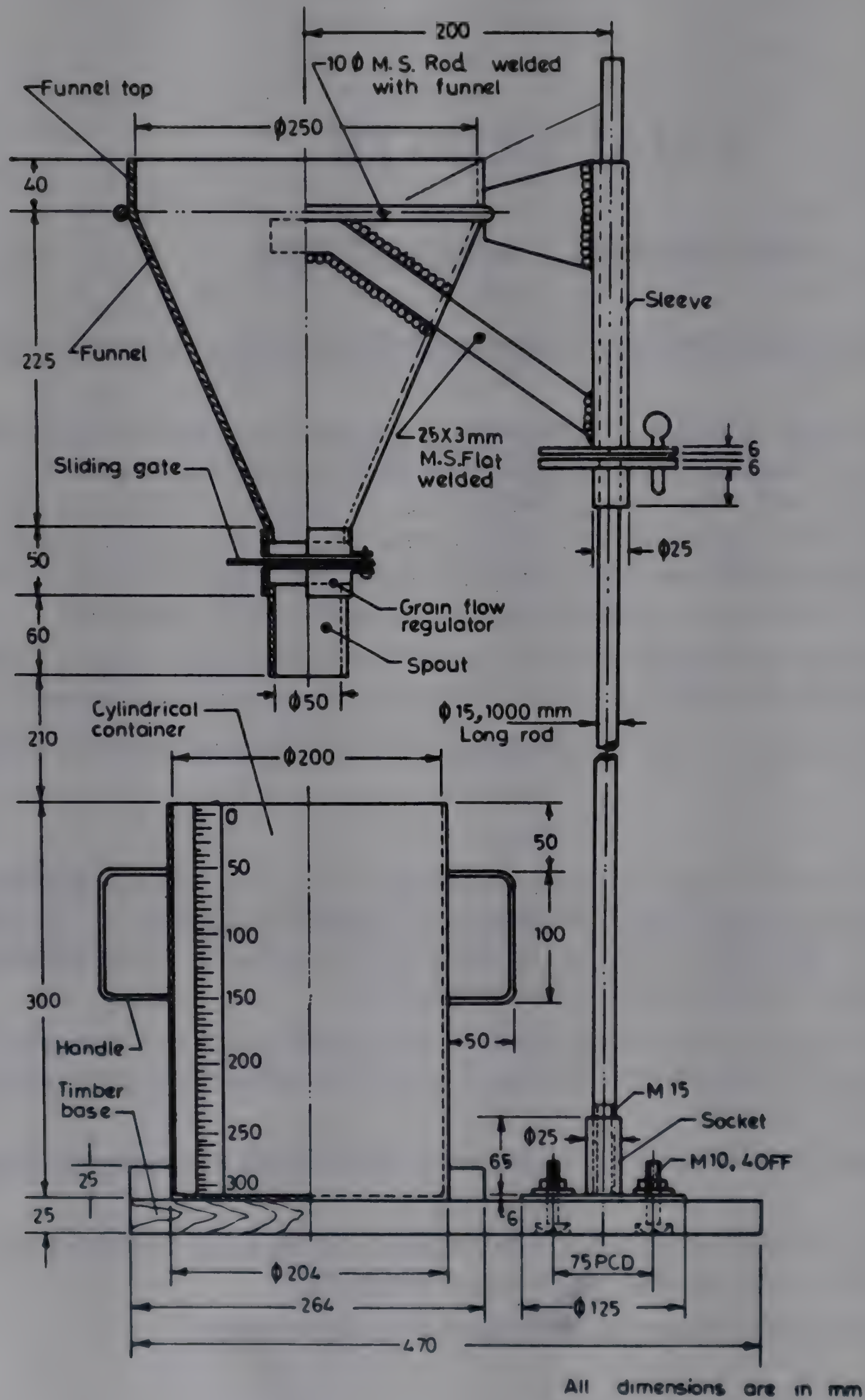


Fig. 4.1. Details of apparatus for determination of angle of respose of grain.

$$\tan\varphi = \frac{d_1 - d_2}{100} = \frac{d_3}{100}$$

$$\text{Angle of repose, } \varphi = \tan^{-1}\left[\frac{(d_3)}{100}\right] \quad \ldots (4.1)$$

Coefficient of external friction

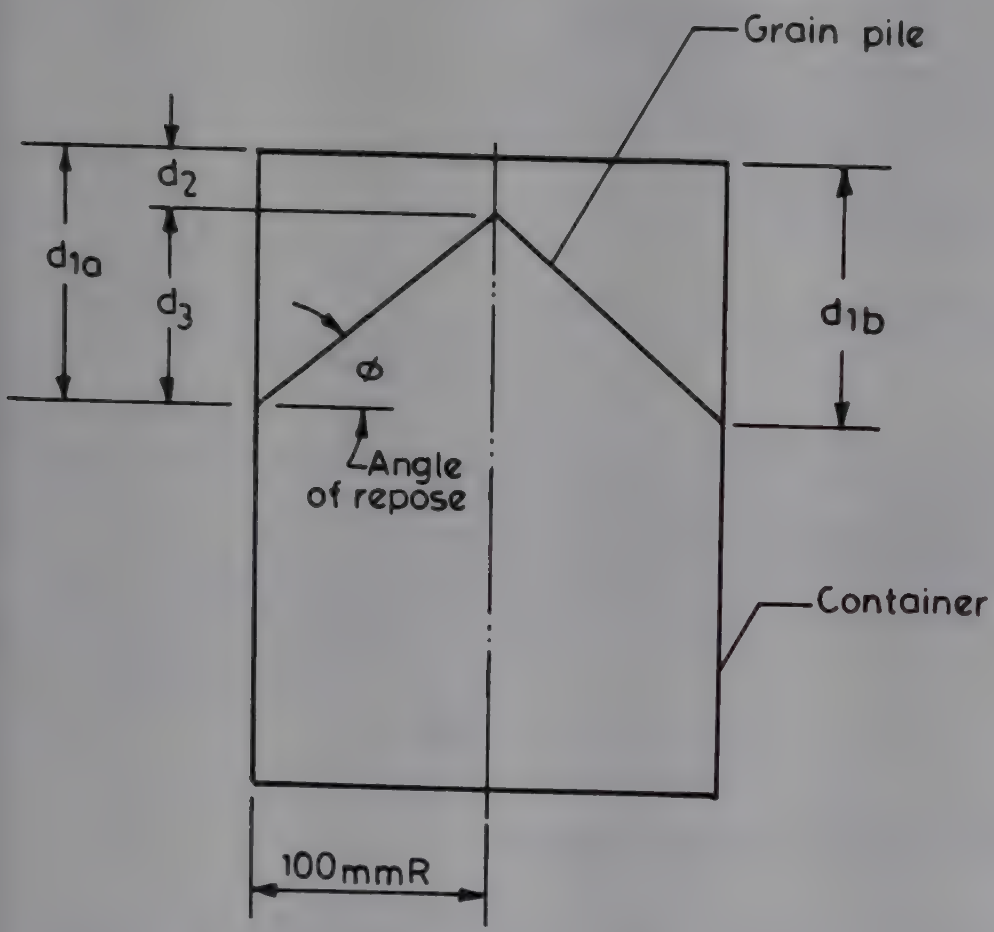


Fig. 4.2. Illustration of angle of respose of grain

The coefficient of external friction could be measured (Donald, 1954) by using a table provided with changeable surfaces (Fig. 4.3).

The box of the size 10.3 cm x 10.3 cm x 5 cm is tied by a cord passing over a pulley and a pan is attached to this cord. The weights were put into the pan until the box starts to slide. These weights (W_1) are noted. Later, the box is filled with sample material and again the weights are put to cause sliding of the box. These weights (W_2) are also noted. The coefficient of external friction could be calculated as;

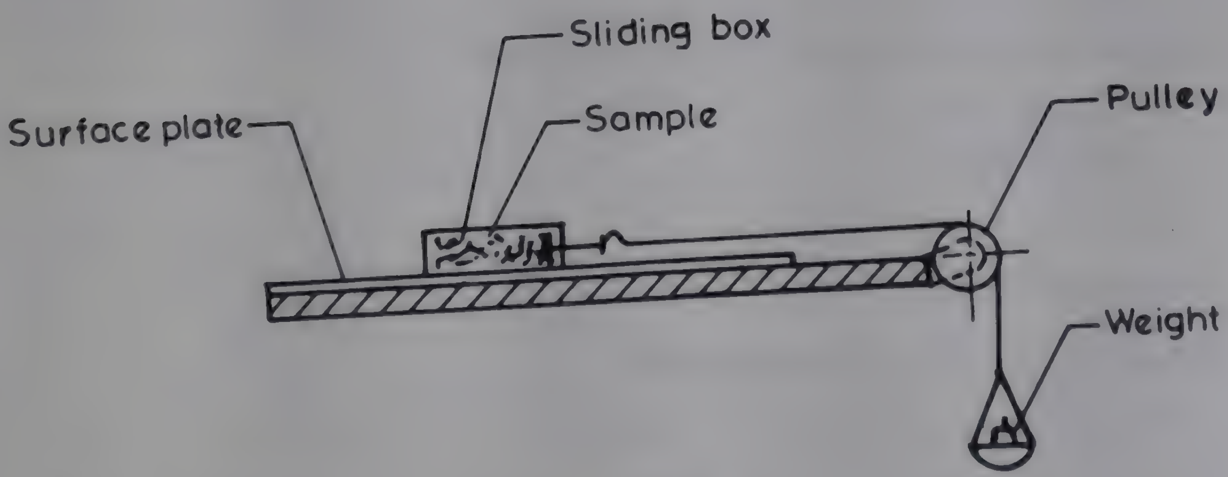


Fig. 4.3. Arrangement for measuring coefficient of external friction.

$$\mu_e = \frac{W_2 - W_1}{W} \qquad \ldots (4.2)$$

Where,

μ_e= coefficient of the external friction,

W_1 = weight to cause sliding of empty box,

W_2 = weight to cause sliding of filled box, and

W = weight of the material inside the box.

Co-efficient of internal friction

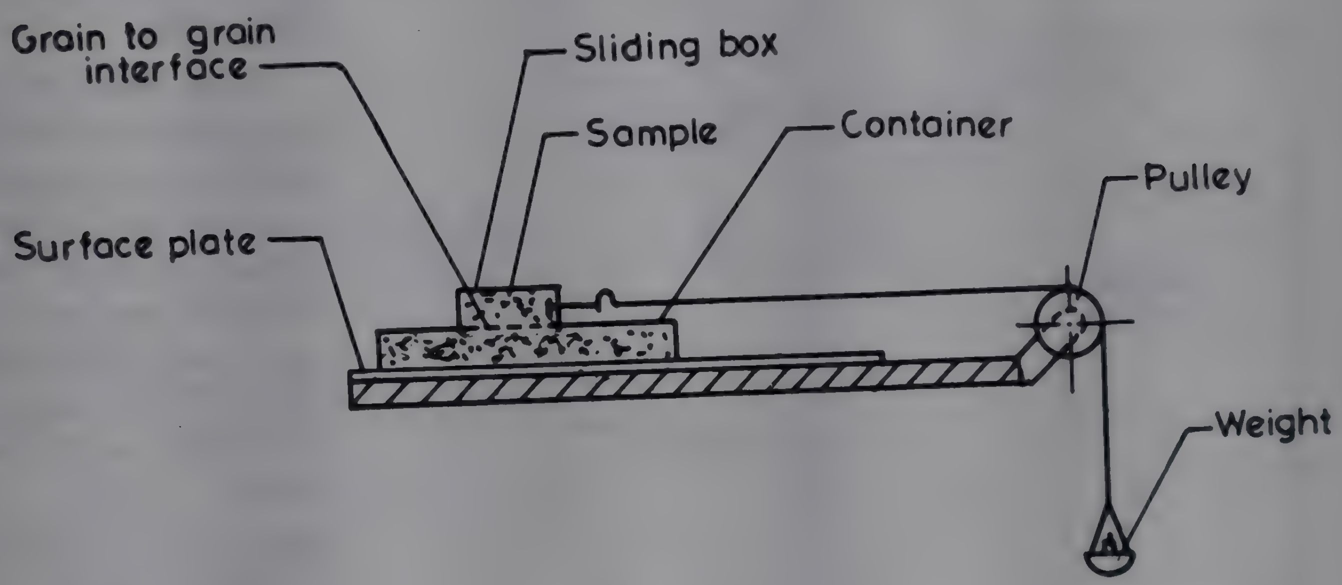


Fig. 4.4. Arrangement for measuring coefficient of internal friction.

For determining the coefficient of internal friction, a box of size 10.0 cm x 10.0 cm x 5 cm is put under the box of size 45 cm x 15 cm x 5 cm (Fig. 4.4).

Both the boxes are filled with the sample material. A box having size of 10 cm x 10 cm x 5 cm is then tied with the cord passing over a pulley attached to a pan. The weights (W_2) are put to cause the sliding of the box. Later, smaller box is made empty and weights (W_1) to cause sliding of it noted. The angle of internal friction could be calculated as;

$$\mu_i = \frac{W_2 - W_1}{W} \qquad \ldots (4.3)$$

Where,

μ_i= coefficient of internal friction,

W_1 = weight to cause sliding of empty smaller box,

W_2 = weight to cause sliding of filled smaller box, and

W = weight of the material inside the smaller box.

Measurement of initial shear stress

A simple apparatus as explained by Stepanoff (Sreenarayan et al., 1985) could be used for measurement of shear stress (τ) for different values of normal stress (σ). The Fig. 4.5 describes the apparatus.

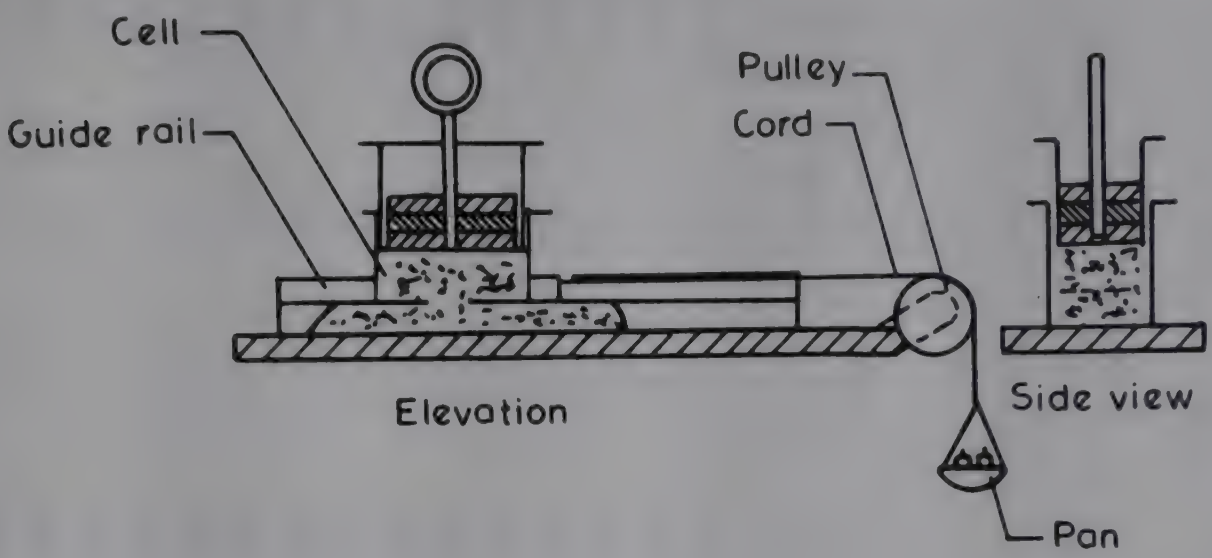


Fig. 4.5. Arrangement for measuring initial shear stress

The sample material is put in a box to the level of the bottom of the cell which is filled with the sample material. On the top of the material, weights are put to provide a desired compaction. Afterwards weights are kept in the pan until the cell begins to move. The normal stress could be calculated as;

$$\sigma = \frac{G_1 + G_2}{F} + h.\gamma \qquad \ldots (4.4)$$

Where,

G_1 = weight of the cell, g

G_2 = weight due to load on top of the cell, g

F = area of the cell, cm^2

h = height of solids in the cell, cm, and

γ = density of the material.

The data obtained during the experimentation are used to plot a curve between shear stress and normal stress to obtain the value of initial shear stress (Fig. 4.6).

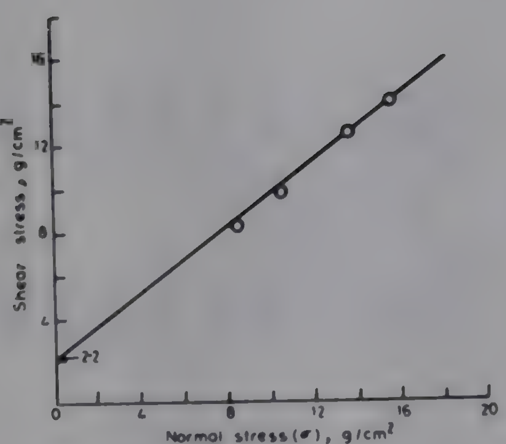


Fig. 4.6. Shear stress v/s normal stress for Bengal gram (*Cicer Arietinum* Linn).

Table 4.1 : Frictional properties of cereals

Grain/ Variety	Moisture content, % (db)	Angle of repose, degree	Co-efficient of internal friction	Co-efficient of static friction							Reference
				Glass	Polyethlene	Wood	Plywood	R.C.C.	Aluminium	G.I. Sheet	
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Bajra											41,127
HB—1	11.1	—	—	—	0.28	—	—	0.36	—	—	
	14.0	—	—	—	0.29	—	—	0.39	—	—	
	17.0	—	—	—	0.31	—	—	0.40	—	—	
	20.0	—	—	—	0.34	—	—	0.42	—	—	
Finger millet											41
CO—11	8.0	—	—	—	0.26	—	—	0.35	—	—	
	10.9	—	—	0.17	—	0.47	—	—	0.39	—	
Maize											127
Ganga—5	< 10.0	27.0	—	—	—	—	0.23	—	—	0.23	
	10.0—19.9	28.0	—	—	—	—	0.25	—	—	0.28	
	20.0—29.9	34.4	—	—	—	—	0.38	—	—	0.39	
	30.0—39.9	34.5	—	—	—	—	0.39	—	—	0.42	
	40.0—49.9	35.0	—	—	—	—	0.41	—	—	0.44	
Local	< 10.0	26.1	—	—	—	—	0.22	—	—	0.23	
	10.0—19.9	28.2	—	—	—	—	0.25	—	—	0.28	
	20.0—29.9	32.8	—	—	—	—	0.27	—	—	0.32	
	30.0—39.9	37.1	—	—	—	—	0.37	—	—	0.38	
	40.0—49.9	38.0	—	—	—	—	0.39	—	—	0.39	
Malan	7.9	25.5	—	—	—	—	0.30	—	—	0.32	
	10.9	26.2	—	—	—	—	0.31	—	—	0.34	
	14.0	27.5	—	—	—	—	0.34	—	—	0.35	
	16.9	28.0	—	—	—	—	0.36	—	—	0.38	
	20.0	28.9	—	—	—	—	0.39	—	—	0.40	
MLU—5	8.2	30.1	—	—	—	—	—	—	—	0.34	

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Vijay–	< 1.0.0	28.4	—	—	—	—	0.23	—	—	0.24	
composite	10.0—19.9	28.7	—	—	—	—	0.25	—	—	0.28	
	20.0—29.9	35.2	—	—	—	—	0.33	—	—	0.40	
	30.0—39.9	35.9	—	—	—	—	0.34	—	—	0.39	
	40.0—49.9	36.0	—	—	—	—	0.36	—	—	0.40	
Paddy											41,173
ADT—27	9.6	25.3	—	—	—	—	—	—	—	—	
	13.2	27.0	—	—	—	—	—	—	—	—	
	16.7	26.8	—	—	—	—	—	—	—	—	
	19.6	28.5	—	—	—	—	—	—	—	—	
	25.6	31.3	—	—	—	—	—	—	—	—	
	31.6	32.0	—	—	—	—	—	—	—	—	
Basmati	13.6	34.7	—	—	—	—	—	—	—	—	
CO—25	9.3	25.9	—	—	—	—	—	—	—	—	
	13.6	27.2	—	—	—	—	—	—	—	—	
	17.2	27.4	—	—	—	—	—	—	—	—	
	20.0	31.8	—	—	—	—	—	—	—	—	
	25.3	28.4	—	—	—	—	—	—	—	—	
	31.6	27.8	—	—	—	—	—	—	—	—	
CO—33	9.9	27.8	—	—	—	—	—	—	—	—	
	12.9	32.3	—	—	—	—	—	—	—	—	
	15.6	32.5	—	—	—	—	—	—	—	—	
	20.0	32.6	—	—	—	—	—	—	—	—	
	25.9	31.0	—	—	—	—	—	—	—	—	
	28.9	31.0	—	—	—	—	—	—	—	—	

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
IR—5	15.9	43.3	—	—	—	—	—	—	—	—	
IR—8	9.4	26.9	—	—	—	—	—	—	—	—	
	10.9	28.4	—	—	—	—	—	—	—	—	
	14.2	34.9	—	—	—	—	—	—	—	—	
	17.6	32.7	—	—	—	—	—	—	—	—	
	22.4	31.2	—	—	—	—	—	—	—	—	
	26.1	31.9	—	—	—	—	—	—	—	—	
	29.9	33.9	—	—	—	—	—	—	—	—	
IR—20	9.4	29.6	—	—	—	—	—	—	—	—	
	12.1	30.7	—	—	—	—	—	—	—	—	
	17.6	31.2	—	—	—	—	—	—	—	—	
	20.3	30.9	—	—	—	—	—	—	—	—	
	26.7	29.1	—	—	—	—	—	—	—	—	
	29.7	29.7	—	—	—	—	—	—	—	—	
IR—579	10.0—19.0	37.2	—	—	—	—	—	—	—	—	
	20.0—30.0	38.2	—	—	—	—	—	—	—	—	
Jaha	—	47.0	—	—	—	—	—	—	—	—	
Jaya	9.60	—	0.56	—	0.52	0.38	—	0.49	—	—	
	< 10.0	33.3	—	—	—	—	—	—	—	—	
	10.0—19.0	33.7	—	—	—	—	—	—	—	—	
	11.8	—	0.57	—	0.53	0.43	—	0.49	—	—	
	14.0	—	0.58	—	0.54	0.46	—	0.53	—	—	
	18.8	—	0.59	—	0.55	0.52	—	0.55	—	—	
	20.0—30.0	35.4	—	—	—	—	—	—	—	—	

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Joshna —351	< 10.0	31.5	—	—	—	—	—	—	—	—	
	10.0—19.0	33.2	—	—	—	—	—	—	—	—	
	20.0—30.0	35.3	—	—	—	—	—	—	—	—	
Manoha-rasali	—	45.0	—	—	—	—	—	—	—	—	
Patnai	14.0	34.0	—	—	—	—	—	—	—	—	
Patnai—23	14.5	37.4	—	—	—	—	—	—	—	—	
Ponmani	9.1	—	—	—	—	—	—	—	—	—	
	9.2	29.4	—	—	—	—	—	—	—	—	
	9.8	—	—	—	—	—	—	—	—	—	
Prasadbhog	—	47.0	—	—	—	—	—	—	—	—	
TKM—6	9.5	28.6	—	—	—	—	—	—	—	—	
	10.9	30.2	—	—	—	—	—	—	—	—	
	15.5	29.8	—	—	—	—	—	—	—	—	
	19.0	30.8	—	—	—	—	—	—	—	—	
	24.1	31.4	—	—	—	—	—	—	—	—	
	30.9	31.6	—	—	—	—	—	—	—	—	
Pearl millet											41
CO—6	9.8	—	—	0.24	—	0.35	—	—	0.31	—	
Sorghum											16
CO—27	9.1	—	—	0.23	—	0.41	—	—	0.30	—	
CSH—5	13.6± 0.5	23.8	—	—	—	—	—	—	—	—	
	19.0 ± 0.5	25.2	—	—	—	—	—	—	—	—	
	25.0 ± 0.5	27.1	—	—	—	—	—	—	—	—	
	31.5 ± 0.5	27.9	—	—	—	—	—	—	—	—	

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
CSH—8R	13.6 ± 0.5	25.1	—	—	—	—	—	—	—	—	
	19.0 ± 0.5	26.9	—	—	—	—	—	—	—	—	
	25.0 ± 0.5	27.3	—	—	—	—	—	—	—	—	
	31.5 ± 0.5	28.9	—	—	—	—	—	—	—	—	
M—35—1	13.6 ± 0.5	27.8	—	—	—	—	—	—	—	—	
	19.0 ± 0.5	29.5	—	—	—	—	—	—	—	—	
	25.0 ± 0.5	31.3	—	—	—	—	—	—	—	—	
	31.5 ± 0.5	32.8	—	—	—	—	—	—	—	—	
SPV—86	13.6 ± 0.5	27.1	—	—	—	—	—	—	—	—	
	19.0 ± 0.5	28.9	—	—	—	—	—	—	—	—	
	25.0 ± 0.5	31.0	—	—	—	—	—	—	—	—	
	31.5 ± 0.5	31.5	—	—	—	—	—	—	—	—	
SPH—202	13.6 ± 0.5	22.5	—	—	—	—	—	—	—	—	
	19.0± 0.5	24.1	—	—	—	—	—	—	—	—	
	25.0 ± 0.5	27.3	—	—	—	—	—	—	—	—	
	31.5 ± 0.5	28.9	—	—	—	—	—	—	—	—	
Wheat											41, 173
HD—2189	8.4	—	—	0.18	—	0.28	—	—	0.26	—	
Sonalika	11.3	—	0.49	—	0.31	0.37	—	—	—	—	
	12.5	—	0.50	—	0.33	0.35	—	0.46	—	—	
	18.3	—	0.54	—	0.34	0.38	—	0.51	—	—	

Table 4.2 : Frictional properties of pulses

Grain/ Variety	Moisutre content, % (db)	Angle of repose, degree	Co-efficient of internal friction	Co-efficient of static friction							Reference
				Glass	Polyethylene	Wood	Plywood	R.C.C.	Allumin-ium	GI Sheet	
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Bengal gram											48
Local	8.1	30.7	0.95	—	—	—	0.56	0.62	—	0.43	
	9.9	—	—	—	—	0.38	—	—	—	—	
	15.0	—	—	—	—	0.40	—	—	—	—	
	19.2	—	—	—	—	0.42	—	—	—	—	
	23.0	—	—	—	—	0.44	—	—	—	—	
	27.2	—	—	—	—	0.51	—	—	—	—	
	31 9	—	—	—	—	0.56	—	—	—	—	
Black gram											143
DU—1	—	42.9	—	—	—	—	—	—	—	—	
DU—2	—	43.1	—	—	—	—	—	—	—	—	
DU—3	—	43.2	—	—	—	—	—	—	—	—	
DU—4	—	43.0	—	—	—	—	—	—	—	—	
JU—77—41	—	42.8	—	—	—	—	—	—	—	—	
JU—78—3	—	42.9	—	—	—	—	—	—	—	—	
JU—78—27	—	42.9	—	—	—	—	—	—	—	—	
Khargone—3	—	42.8	—	—	—	—	—	—	—	—	
Local	4.7	28.6	—	—	—	—	—	—	—	—	
	4.9	—	—	0.18	—	0.29	—	—	0.29	—	
	7.1	24.3	0.63	—	—	—	0.51	0.52	—	0.46	
N—55	—	43.3	—	—	—	—	—	—	—	—	
Pant—U—30	—	42.9	—	—	—	—	—	—	—	—	
PDU—1	—	42.8	—	—	—	—	—	—	—	—	

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
PDU—3	—	42.8	—	—	—	—	—	—	—	—	
PU—26	—	42.3	—	—	—	—	—	—	—	—	
PU—30	—	43.0	—	—	—	—	—	—	—	—	
RU—2	—	43.0	—	—	—	—	—	—	—	—	
Sardomage	—	43.0	—	—	—	—	—	—	—	—	
T—9	—	42.8	—	—	—	—	—	—	—	—	
UG-201	—	42.8	—	—	—	—	—	—	—	—	
UG—218	—	42.9	—	—	—	—	—	—	—	—	
UG—236	—	42.9	—	—	—	—	—	—	—	—	
UH—28	—	42.6	—	—	—	—	—	—	—	—	
UH—80—4	—	42.9	—	—	—	—	—	—	—	—	
UH—80—7	—	43.1	—	—	—	—	—	—	—	—	
UPG—82—5	—	42.9	—	—	—	—	—	—	—	—	
UPU—80—3—5	—	42.8	—	—	—	—	—	—	—	—	
UPU—83—2	—	42.9	—	—	—	—	—	—	—	—	
Green gram											143
J—45	—	43.2	—	—	—	—	—	—	—	—	
Kopargaon	—	43.9	—	—	—	—	—	—	—	—	
K—851	—	43.1	—	—	—	—	—	—	—	—	
Local	6.7	25.1	0.58	—	—	—	0.34	0.41	—	0.34	
MH—81—7	—	43.1	—	—	—	—	—	—	—	—	
MH—309	—	43.2	—	—	—	—	—	—	—	—	
Pant—Mung—2	—	42.9	—	—	—	—	—	—	—	—	
PS—16	—	43.1	—	—	—	—	—	—	—	—	
Pusa Baisakhi	—	43.7	—	—	—	—	—	—	—	—	
Puss—105	—	42.7	—	—	—	—	—	—	—	—	

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Rahuri—1	—	42.9	—	—	—	—	—	—	—	—	
UPM—82—4	—	42.8	—	—	—	—	—	—	—	—	
UPM—83—10	—	43.2	—	—	—	—	—	—	—	—	
11—395	—	42.9	—	—	—	—	—	—	—	—	
Horsegram											173
Local	—	24.0	—	—	0.45	—	—	—	—	0.48	
Lentil			—	—	—	—	—	—	—	—	
Local	8.2	25.7	0.51	—	—	—	0.49	0.53	—	0.47	48
Pigeonpea											48,173
ICPL—1	—	20.3	0.41	—	—	—	—	—	—	—	
ICPL—6	—	20.6	0.40	—	—	—	—	—	—	—	
ICPL—87	—	21.1	0.42	—	—	—	—	—	—	—	
ICPL—131	—	22.9	0.38	—	—	—	—	—	—	—	
ICPL—138	—	21.4	0.42	—	—	—	—	—	—	—	
ICPL—211	—	22.8	0.36	—	—	—	—	—	—	—	
ICPL—227	—	21.9	0.42	—	—	—	—	—	—	—	
ICPL—270	—	20.1	0.40	—	—	—	—	—	—	—	
ICPL—332	—	22.8	0.37	—	—	—	—	—	—	—	
ICPL—333	—	22.1	0.37	—	—	—	—	—	—	—	
ICPL—7035	—	22.1	0.38	—	—	—	—	—	—	—	
ICPL—84060	—	23.3	0.38	—	—	—	—	—	—	—	
LOCAL	8.7	21.1	0.40	—	—	—	0.50	0.51	—	0.49	
T—21	9.2	—	0.34	—	0.25	0.27	—	0.31	—	—	
	10.8	—	0.34	—	0.27	0.27	—	0.31	—	—	
	14.1	—	0.35	—	0.28	0.28	—	0.31	—	—	
	18.9	—	0.38	—	0.29	0.32	—	0.35	—	—	

Table 4.3: Frictional properties of oilseeds

Seed/ Variety	Moisture content, % (db)	Angle of repose, degree	Co-efficient of internal friction	Co-efficient of static fricion								Reference
				Allumini um	Glass	Mild steel	Ply-wood	Polyet-hylene	R.C.C.	G.I. sheet	Wood	
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
Castor												51
Local												
Small	5.4	47.8	—	—	—	—	—	—	—	0.86	—	
Medium	5.3	46.2	—	—	—	—	—	—	—	0.57	—	
Large	4.9	45.4	—	—	—	—	—	—	—	0.85	—	
Gingelly												147
Co-1	2.1	—	0.39	—	0.23	—	0.47	—	—	—	—	
Local	2.1	31.6	—	—	—	—	—	—	—	—	—	
Gobisarson												142
Local	4.2	—	0.64	0.43	—	—	—	—	—	—	0.53	
	12.4	—	0.71	0.49	—	—	0.39	—	—	—	—	
	18.9	—	0.84	0.59	—	—	0.55	—	—	—	—	
Groundnut (pod)												75,137
JL—24												
Single kernel ellipsoid	10.3	—	—	—	—	0.60	—	—	—	—	—	
Double kernel ellipsoid	10.3	—	—	—	—	0.57	—	—	—	—	—	
Paired ellipsoid	10.3	—	—	—	—	0.57	—	—	—	—	—	
Cassinoids	10.3	—	—	—	—	0.59	—	—	—	—	—	
Triple kernel ellipsoid	10.3	—	—	—	—	0.57	—	—	—	—	—	
GAUG—1	5.3	—	—	—	0.45	0.47	0.56	—	—	—	—	

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
	13.6	—	—	—	0.52	0.51	0.60	—	—	—	—	
	20.5	—	—	—	0.53	0.54	0.62	—	—	—	—	
	28.2	—	—	—	0.57	0.56	0.67	—	—	—	—	
GAUG—10	5.3	—	—	—	0.42	0.42	0.53	—	—	—	—	
	13.6	—	—	—	0.47	0.46	0.57	—	—	—	—	
	20.5	—	—	—	0.49	0.48	0.59	—	—	—	—	
	28.2	—	—	—	0.52	0.51	0.62	—	—	—	—	
GG—2	5.3	—	—	—	0.40	0.45	0.56	—	—	—	—	
	13.6	—	—	—	0.49	0.49	0.49	—	—	—	—	
	20.5	—	—	—	0.51	0.54	0.61	—	—	—	—	
	28.2	—	—	—	0.56	0.55	0.65	—	—	—	—	
GG—11	5.3	—	—	—	0.40	0.41	0.52	—	—	—	—	
	13.6	—	—	—	0.44	0.42	0.55	—	—	—	—	
	20.5	—	—	—	0.46	0.47	0.58	—	—	—	—	
	28.2	—	—	—	0.50	0.50	0.62	—	—	—	—	
M—13	5.3	—	—	—	0.48	0.48	0.57	—	—	—	—	
	13.6	—	—	—	0.56	0.53	0.51	—	—	—	—	
	20.5	—	—	—	0.61	0.60	0.65	—	—	—	—	
	28.2	—	—	—	0.63	0.61	0.72	—	—	—	—	

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
Linseed												147
LC-54	4.0	20.1	—	0.56	—	0.55	0.49	—	—	—	—	
	11.0	21.5	—	0.53	—	0.52	0.32	—	—	—	—	
	15.5	24.9	—	0.63	—	0.64	0.60	—	—	—	—	
Raya (Rapeseed)												142,173
RLM—619	4.0	18.4	—	0.43	—	0.56	0.50	—	—	—	—	
	4.2	—	0.68	0.43	—	—	0.50	—	—	—	—	
	11.5	21.1	—	0.47	—	0.39	0.45	—	—	—	—	
	13.0	—	0.76	0.47	—	—	0.45	—	—	—	—	
	15.7	27.0	—	0.59	—	0.63	0.56		—	—	—	
	18.6	—	0.88	0.59	—	—	0.56	—	—	—	—	
Sesamum												147
Pb No. -1	3.8	26.1	—	0.69	—	0.83	0.56	—	—	—	—	
	12.0	28.3	—	0.76	—	0.65	0.66	—	—	—	—	
	16.0	31.7	—	0.86	—	0.86	0.82	—	—	—	—	
Soybean												41,143
Ankur	—	25.5	0.32	—	—	—	—	—	—	—	—	
Bragg	9.4	—	0.44	—	—	—	0.27	—	0.33	—	0.29	
	10.8	—	0.46	—	—	—	0.28	—	0.34	—	0.30	
	12.4	—	0.46	—	—	—	0.29	—	0.35	—	0.31	
	19.0	—	0.49	—	—	—	0.31	—	0.41	—	0.38	
	—	27.2	0.26	—	—	—	—	—	—	—	—	

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
DS–76–1–29	—	21.8	0.34	—	—	—	—	—	—	—	—	
JS–72–44	—	30.3	0.32	—	—	—	—	—	—	—	—	
JS–75–19	—	24.6	0.33	—	—	—	—	—	—	—	—	
JS–75–45	—	21.1	0.31	—	—	—	—	—	—	—	—	
JS–76–205	—	24.7	0.33	—	—	—	—	—	—	—	—	
JS–76–259	—	27.3	0.33	—	—	—	—	—	—	—	—	
JS–76–280	—	23.1	0.37	—	—	—	—	—	—	—	—	
JS–80–21	—	22.2	0.29	—	—	—	—	—	—	—	—	
Kalituar	—	23.7	0.34	—	—	—	—	—	—	—	—	
Local	6.6	25.5	—	0.26	0.18	—	0.28	—	0.28	—	—	
	7.5	25.5	—	—	—	—	—	—	—	—	—	
MACS–75	—	25.8	0.32	—	—	—	—	—	—	—	—	
N–19	—	22.5	0.28	—	—	—	—	—	—	—	—	
PK–472	—	25.8	0.35	—	—	—	—	—	—	—	—	
T–49	—	28.1	0.34	—	—	—	—	—	—	—	—	
Sunflower (head)												113
Morden	9.3	—	0.49	—	—	—	—	—	—	—	—	
	14.9	—	0.49	—	—	—	—	—	—	—	—	
	19.8	—	0.51	—	—	—	—	—	—	—	—	
Sunflower (seed)												41,113,173
CMS–234–A	—	28.7	—	—	—	0.62	—	—	—	0.57	—	
CO–1	4.4	—	—	0.35	0.29	—	0.48	—	—	—	—	
GD–1	—	22.0	—	—	—	0.55	—	—	—	0.55	—	
KBSH–1	—	24.6	—	—	—	0.55	—	—	—	0.55	—	
Local	4.4	27.6	—	—	—	—	—	—	—	—	—	
Morden	8.3	33.20	—	—	—	—	—	—	—	—	—	
	10.9	34.70	—	—	—	—	—	—	—	—	—	
	20.0	42.40	—	—	—	—	—	—	—	—	—	
	7.7	—	—	0.38	—	0.40	—	0.42	0.36	0.37	0.45	
	—	28.10	—	—	—	0.61	—	—	—	0.60	—	
RHA–274	—	27.0	—	—	—	0.62	—	—	—	0.53	—	

Various research workers have carriedout studies on the frictional properties for cereals (bajra, finger millet, maize, paddy, pearl millet and sorghum); pulses (Bengal gram, black gram, green gram, horsegram, lentil and pigeon pea); oilseeds (gingelly, gobisarson, groundnut, linseed, rapeseed, sesamum, soybean and sunflower) and spices (aniseed, coriander seed, cumin seed and fenugreek seed) for Indian varieties at different moisture contents. Some of these properties such as, angle of repose, coefficient of static friction and co-efficient of internal friction of grains are listed in the Tables 4.1-4.4.

Table 4.4 : Frictional properties of spices and gorgon nut

Seed/Variety	Moisture content, % (db)	Angle of repose, degree	Coefficient of static friction (on GI surface)	Reference
Aniseed (local)				49
Coarse	10.8	33.2	0.91	
Fine	9.7	36.4	0.96	
Coriander seed				86
Local	10.4	17.2	0.76	
Cumin seed				172
Local	7.6	30.4	0.80	
Fenugreek seed				172
Local	8.9	26.8	0.43	
Gorgon nut (Makhana)				
Local	15–60	21.1–22.3	0.38–0.48	70

CHAPTER - V

AERODYNAMIC PROPERTIES

In handling and processing of agricultural products, often air is used as a carrier for transport or for separating the desirable product from the unwanted materials. Aerodynamic properties such as, terminal velocity and drag coefficient are needed for air conveying or pneumatic separation of materials. An air velocity greater than terminal velocity lifts the particle. To allow gentle fall of a particle, the air velocity could be adjusted to a point just below the terminal velocity.

Terminal velocity of grains in air can be measured using vertical air tunnel (Fig. 5.1). In this, the range of different air velocities could be obtained by adjustable speed motor attached with blower. The air velocity at which the grain remains in suspension is called ***terminal velocity.***

Once the terminal velocity of grain in air is known, the following relationship (Gill, 1969) can be used for the calculation of drag coefficient :

$$3\,\rho_f\, C_D V_t^2 = 4 d_n (\rho_p - \rho_f) g \theta^{1/2} \qquad \ldots (5.1)$$

Where,

ρ_f = density of air,

V_t = terminal velocity,

C_D = drag coefficient,

d_n = nominal diameter of tunnel,

ρ_p = particle density,

θ = sphericity, and

g = gravitational acceleration.

The nominal diameter, d_n is easily found since it being the diameter of the sphere having the same volume as the solid under consideration.

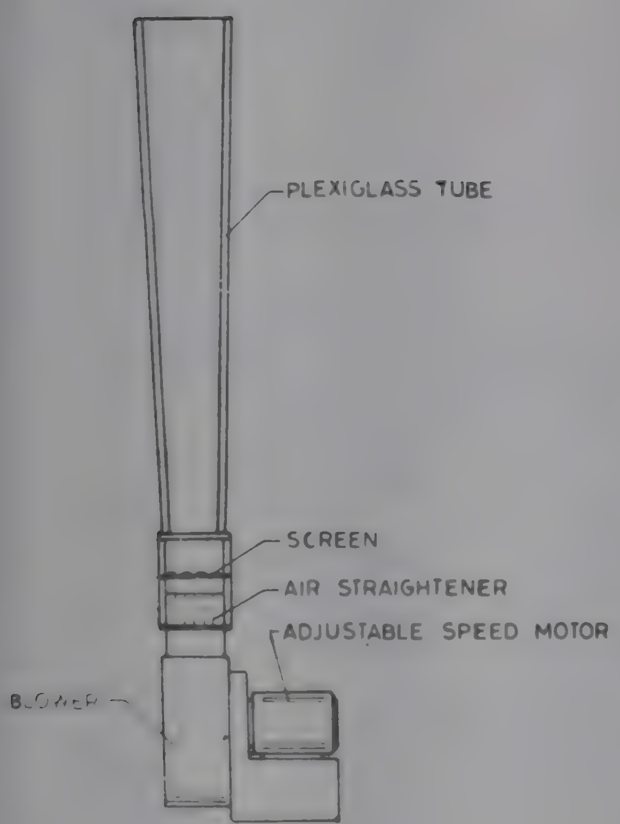


Fig. 5.1. Vertical air tunnel for terminal velocity determination in air.

Various research workers have carriedout studies on the aerodynamic properties for cereals (maize, rice, sorghum and wheat), pulses (Bengal gram, black gram, cowpea, green gram, pea and pigeon pea), oilseeds (castor, gingelle, groundnut, mustard, niger and soybean), fruit and vegetable seeds (long melon, musk melon and water melon) and spices (aniseed, coriander seed, cumin seed and fenugreek seed) for Indian varieties at different moisture contents. Some of these properties such as, terminal velocity, carrying velocity and drag coefficient are listed in the Tables 5.1-5.5.

Table 5.1 : Aerodyamic properties of cereals

Crop/Variety	Terminal velocity, m/s		Drag co-efficient		Reference
	Range	Mean	Range	Mean	
Maize					41
Ganga	13.10—14.15	13.85	0.52—0.64	0.55	
Kisan Composite	11.21—13.80	12.44	0.52—0.87	0.65	
Rice					41
CR—28—25	6.95—7.20	7.08	0.61—0.80	0.70	
IR—8—228—3	6.85—7.29	7.11	0.63—0.96	0.78	
Bran 11.5*	—	1.59	—	—	
Broken 11.6*	—	4.05	—	—	
Germ 8.8*	—	3.28	—	—	
Sorghum					41
HB—MSCK—60—15—84	10.12—10.74	10.31	0.40—0.58	0.51	
Local	10.18—10.35	10.29	0.35—0.52	0.44	
Wheat					35,41
NP720	9.50—9.85	9.70	0.48—0.69	0.60	
PB593	9.93—10.10	10.02	0.50—0.67	0.60	
Wheat chaff	5.04—8.96	7.00	—	—	
Wheat stalk nodules	5.88—8.96	7.42	—	—	

* Moisture content, % (db)

Table 5.2 : Aerodynamic properties of pulses

Crop/Variety	Terminal velocity, m/s		Drag co-efficient		Reference
	Range	Rean	Range	Mean	
Bengal gram					41
BR—77	11.75—12.55	11.81	0.59—0.69	0.64	
Black gram					41
72—7	10.89—11.28	11.07	0.40—0.55	0.46	
Cow pea					41
T—2	12.35—13.29	12.48	0.44—0.52	0.49	
Green gram					41
HB—45	10.60—10.80	10.70	0.42—0.53	0.48	
Pea					41
Bonniville	11.12—12.50	11.92	0.50—0.76	0.61	
VRS—6115	14.25—15.00	14.63	0.38—0.55	0.45	
Pegeon pea					41
C—11	13.39—13.90	13.48	0.39—0.49	0.43	

Table 5.3 : Aerodynamic properties of oilseeds

Crop/Variety	Moisture content, % (db)	Terminal velocity, m/s		Drag co-effiient		Reference
		Range	Mean	Range	Mean	
1.	2.	3.	4.	5.	6.	7.
Castor						51,54
Local						
Small	5.4	—	10.20	—	—	
Medium	5.3	—	13.93	—	—	
Large	4.9	—	11.99	—	—	
NPH—1	7.5	4.20—4.60	4.40	—	—	
	13.6	4.60—5.80	5.50	—	—	
	21.9	5.90—6.76	6.33	—	—	
	31.6	6.80—7.00	8.00	—	—	
Gingelle	—	—	4.42	—	—	
Groundnut (hull)						54
Half	7.2	—	3.50	—	—	
One—fourth	6.3	—	3.37	—	—	
Bits	8.2	—	2.25	—	—	
Groundnut (kernel)						41,75
JL—24	4.4	10.76—15.39	—	—	—	
RS—1	—	12.31—13.78	13.23	0.52—0.64	0.59	
Groundnut (pod) JL—24						75
Single kernel ellipsoid	10.3	8.94—14.60	12.56	—	--	
Double kernel ellipsoid	10.3	9.71—14.24	12.19	—	—	
Paired ellipsoid	10.3	8.17—13.02	10.99	—	—	
Cassinoids	10.3	7.32—12.53	10.94	—	—	
Triple kernel ellipsoid	10.3	9.81—14.87	12.92	—	—	
Mustard	—	—	3.26	—	—	41
Niger	10.1	—	4.59	—	—	41
Soybean						41
Lee	—	13.30—14.55	14.17	0.33—0.51	0.41	
Punjab—1	—	12.30—13.92	13.40	0.38—0.62	0.47	

Table 5.4 : Aerodynamic properties of some fruit seeds

Fruit	Carrying velocity, m/s	Reference
Long melon		127
Dry		
Hull	2.33	
Kernel	7.22	
Seed	7.55	
Wet		
Hull	2.89	
Kernel	7.78	
Seed	8.33	
Muskmelon		127
Dry		
Hull	2.44	
Kernel	7.00	
Seed	7.44	
Wet		
Hull	2.78	
Kernel	7.78	
Seed	8.22	
Watermelon		127
Dry		
Hull	4.55	
Kernel	7.66	
Seed	8.33	
Wet		
Hull	4.89	
Kernel	8.33	
Seed	9.11	

Table 5.5 : Aerodynamic properties of spices

Seed/Variety	Moisture content, % (db)	Terminal velocity, m/s	Reference
Aniseed (local)			49
Coarse	10.8	5.0	
Fine	9.7	3.6	
Coriander seed			86
Local	10.4	5.8	
Cumin Seed			172
Local	7.6	3.1	
Fenugreek seed			172
Local	8.9	4.2	

CHAPTER-VI

RHEOLOGICAL PROPERTIES

Mechanical damage to seeds and grains which occur in harvesting, threshing and handling can affect the quality of the final product. Rheological properties such as, compressive strength, impact, shear resistance etc., are important and in some cases necessary engineering data in studying size reduction of grains as well as resistance to mechanical injury to the seed under mechanical threshing and handling.

Compression tests of intact biological materials provide an objective method for determining mechanical properties significant in quality evaluation and control, maximum allowable load for minimizing mechanical damage, and minimum energy requirements for size reduction.

Determination of compressive properties requires the production of a complete force-deformation curve. For production of a force deformation curve (Fig. 6.1), the use of fully automatic testing machine known as Universal Testing Machine (INSTRON) has become popular in recent years.

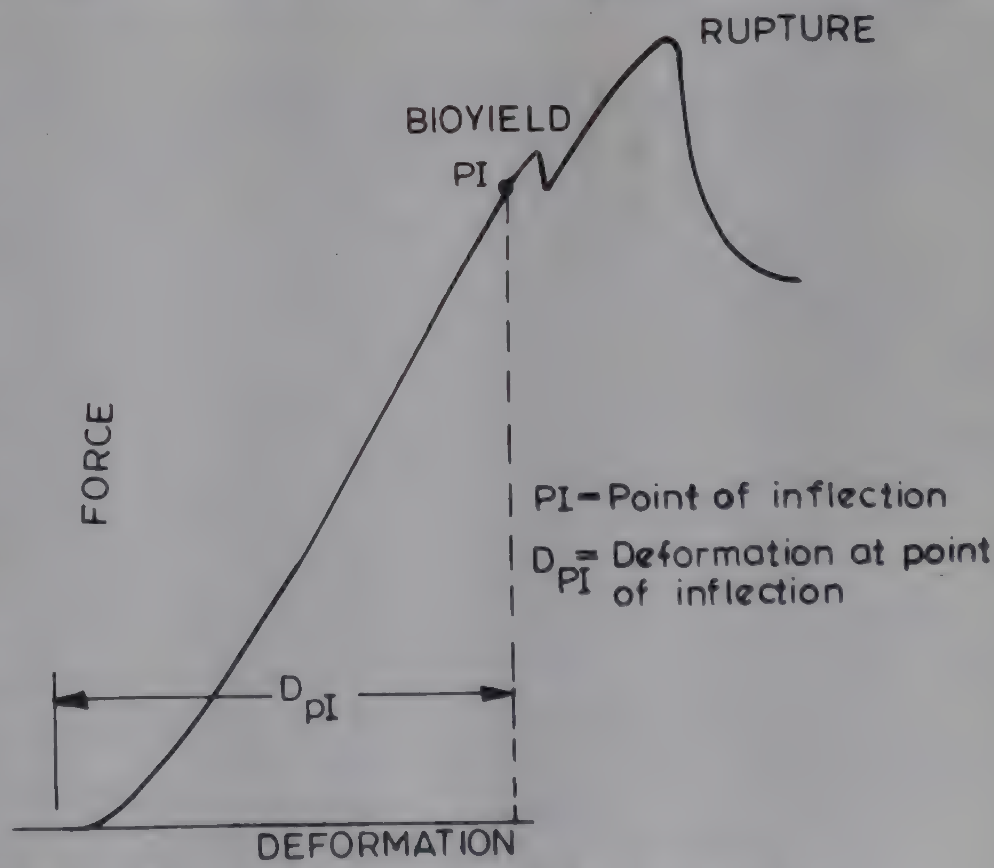


Fig. 6.1. Force deformation curve for material with bioyield point.

Some of the important points which should be kept in mind during compression test using 'INSTRON' are as follows (Mohsenin, 1980) :

1. Conduct the test under laboratory atmosphere of constant relative humidity and temperature. If possible, tests should be conducted under laboratory conditions of 20°C ± 5°C and 50 per cent relative humidity ± 5 per cent.
2. Place the specimen in the testing machine under the compression tool, taking care

to align the center of the tool with the peak of the curvature of the test specimen.

3. Set the speed control at the desired rate and calibrate the recording chart for load and displacement. Normally, the speed of testing (cross head speed) shall be chosen on the basis of the sensitiveness of the specimen to loading rate. For grain, the speed of 1.25 mm per minute ± 50 per cent shall be specified.

4. Start the machine and record the complete force-deformation curve through the point of rupture. When testing small, hard specimens such as, grains, the deflections of most load cells can not be considered negligible. For this reason, either proof shall be given that the load cell deflection is negligible or the deflection is determined and deducted from the recorded deformation.

5. Because of the large variance inherent in biological materials, each experiment shall be statistically designed with sufficient number of replications to result in an acceptable level of confidence in so far as significant differences are concerned. The variation due to shape, size, age and cellular structure are normally such that at least a minimum of twenty specimens are required to be tested for each sample.

6. For each series of tests, calculate the mean and standard deviation.

Various research workers have carriedout studies on the rheological properties for cereals (finger millet, maize, paddy, pearl millet, sorghum and wheat); pulses (Bengal gram, black gram, cowpea, green gram, lentil and pigeon pea); oilseeds (castor, gingelly, soybean and sunflower), fruit and vegetable seeds (brinjal, pumkin, summer melon, tomato and water melon) and spices (aniseed, coriander seed and cumin seed) for Indian varieties at different moisture contents. Some of these properties such as, relative hardness number, hardness, coefficient of restitution, crushing load, initial shear stress and ultimate compressive load are listed in the Tables 6.1-6.5.

Table 6.1 : Rheological properties of cereals

Grain/Variety	Moisture content, % (db)	Relative hardness number	Hardness, kg	Co-efficient of restitution	Crushing load, kg	Reference
1.	2.	3.	4.	5.	6.	7.
Finger millet						16,41
CO—6	10.9	—	1.16	—	—	
Maize						16,41
Ganga—2	9.9	140	—	—	—	
	12.4	63	—	—	—	
	14.9	53	—	—	—	
Ganga—3	9.9	94	—	—	—	
	12.4	70	—	—	—	
	14.9	58	—	—	—	
Ganga—5	9.9	78	—	—	—	
	12.4	63	—	—	—	
	14.9	56	—	—	—	
MLU—5	8.2	—	22.84	—	—	
Paddy						41
Local	12.6	—	—	0.09	—	

Table contd...

1.	2.	3.	4.	5.	6.	7.
Ponmani	9.8	—	6.90	—	—	
Pearl millet						41
CO—6	9.8	—	2.70	—	—	
Sorghum						41
CO—27	.9.1	—	7.77	—	—	
Wheat						35,41,173
C—306	—	—	—	—	8.63	
CPAN—1676	—	—	—	—	9.75	
HD—2189	8.4	—	8.20	—	—	
HD—2204	—	—	—	—	10.06	
HD—2281	—	—	—	—	9.96	
HD—2285	—	—	—	—	10.50	
HS—86	—	—	—	—	11.15	
Kalyan Sona	6.2	—	—	—	5.17	
	7.8	—	—	—	5.75	
	8.6	—	—	—	5.81	
	13.7	—	—	—	6.28	
	26.1	—	—	—	3.24	
	30.0	—	—	—	1.36	
	31.7	—	—	—	0.90	
	37.4	—	—	—	1.04	
	41.8	—	—	—	1.46	
Local	16.9	—	—	0.09	—	
Malviya—12	16.9	—	—	—	10.70	
S—227	9.9	88	—	—	—	
	12.4	47	—	—	—	
	14.9	31	—	—	—	
S—308	9.9	100	—	—	—	
	12.4	47	—	—	—	
	14.9	31	—	—	—	
Sonalika	—	—	—	—	9.80	
UP—115	—	—	—	—	10.60	
UP—262	—	—	—	—	12.00	
UP—368	—	—	—	—	9.98	
UP—2003	—	—	—	—	10.11	
VL—421	—	—	—	—	12.56	

Table 6.2 : Rheological properties of pulses

Grain/Variety	Moisture content, % (db)	Relative hardness, number	Hardness, kg	Co-efficient of restitution	Crushing load, kg	Initial shear stress, g/cm^2	Reference
1.	2.	3.	4.	5.	6.	7.	8.
Bengalgram							41,48
Local	8.1	—	—	—	20.10	2.20	
T—3	9.9	60	—	—	—	—	
	12.4	47	—	—	—	—	
	14.9	41	—	—	—	—	
T—730	9.9	63	—	—	—	—	
	12.4	56	—	—	—	—	
	14.9	47	—	—	—	—	
Blackgram							48
CO—4	4.3	—	2.0	—	—	—	
Local	7.1	—	—	—	3.50	2.00	
Cowpea							41,48
Local	6.7	—	—	—	6.00	2.00	
Green gram							48
Local	6.7	—	—	—	1.90	1.60	
Lentil							48
Local	8.2	—	—	—	5.70	1.70	
Pigeon pea							48
Local	8.7	—	—	—	11.50	2.00	
	14.2	—	—	0.17	—	—	

Table 6.3 : Rheological properties of oilseeds

Grain/Variety	Moisture content, % (db)	Relative hardness, number	Hardness, kg	Co-efficient of restitution	Crushing load, kg	Ultimate compressive load, kg	Reference
1.	2.	3.	4.	5.	6.	7.	8.
Castor							51,54
Local							
Small	5.4	—	—	—	6.8	—	
Medium	5.3	—	—	—	11.2	—	
Large	4.9	—	—	—	6.7	—	
NPH—1	7.5	—	—	—	6.60	—	
	13.6	—	—	—	5.16	—	
	21.9	—	—	—	6.30	—	
	31.6	—	—	—	8.00	—	
Gingelly							41
CO—1	2.1	—	1.50	—	—	—	
Soybean							41,143
Ankur	—	—	—	—	10.0	4.6	
	—	—	—	—	8.20	—	
Bragg	7.7	56	—	—	—	—	
	11.1	52	—	—	—	—	
	13.6	38	—	—	—	—	
	—	—	—	—	12.2	5.4	
CO—1	7.0	—	8.14	—	—	—	
DS—76—1—29	—	—	—	—	7.30	5.60	
JS—2	—	—	—	—	10.50	7.60	
JS—72—44	—	—	—	—	8.10	3.80	
JS—75—19	—	—	—	—	10.20	4.70	
JS—75—45	—	—	—	—	8.20	3.50	
JS—76—205	—	—	—	—	8.20	3.00	
JS—76—280	—	—	—	—	10.20	4.20	
JS—80—21	—	—	—	—	10.50	5.50	
Kalituar	—	—	—	—	6.70	3.00	
Local	17.3	—	—	0.18	—	—	
MACS—75	—	—	—	—	8.60	5.30	
N—19	—	—	—	—	8.40	4.00	
PK—472	—	—	—	—	10.30	4.40	
T—49	—	—	—	—	8.80	4.00	
Sunflower							173
CO—1	4.4	—	3.84	—	—	—	

Table 6.4 : Rheological properties of fruits and vegetable seeds

Seed/Variety	Moisture content, % (db)	Hardness, kg	Reference
1.	2.	3.	4.
Brinjal			148
Local	3.6	2.87	
Pumpkin			148
Local	10.9	10.69	
Summer melon			148
Local	4.5	1.20	
Tomato			148
Rupali	3.6	2.87	
Water melon			148
Baby sugar	4.7	4.10	

Table 6.5 Rheological properties of spices

Seed/Variety	Moisture content, % (db)	Crushing load, kg	Reference
1.	2.	3.	4.
Aniseed (local)			49
Coarse	10.8	2.7—6.8	
Fine	9.7	2.4—6.9	
Coriander seed			86
Local	10.4	0.95—1.30	
Cumin seed			172
Local	7.6	2.4—3.0	

CHAPTER-VII

THERMAL PROPERTIES

Any process involving heating and cooling requires a knowledge of the thermal properties of the substances being processed. Many of the food grains and the products are subjected to various types of thermal processing before they are placed at the disposal of the consumers. This calls for the information about the specific heat, thermal conductivity, thermal diffusivity and latent heats associated with the various food materials. The knowledge of specific heat is also important in aeration, drying, milling etc. of food grains.

Specific heat is the amount of heat required to raise the temperature of a unit mass of grain by 1°C. Specific heat of the food grains can be determined by any of the two methods described below (IS: 10699-1983):

A. **Calorimetric Method**

Apparatus : calorimeter

Procedure

1. Heat 30 g of foodgrain sample to a constant temperature (max. 66°C), avoiding over-heating which may alter the composition of the foodgrain. Fill the calorimeter cup with water of known temperature and dip the material in it. Stir the mixture well and note the final temperature, when it becomes steady.
2. Calculation

$$\text{Specific heat of food grain (cal/g. °C)} = \frac{(M_2C_1+M_3C_2)\ (\Delta t_2-\theta)}{M_1(\Delta t_1+\theta)} \qquad \ldots (7.1)$$

Where,

M_1 = mass of the foodgrain sample, g

M_2 = mass of the calorimeter cup, g

M_3 = mass of water, g

C_1 = specific heat of calorimeter cup,cal/g.°C

C_2 = specific heat of water, cal/g.°C

Δt_1 = temperature change of the sample, °C

Δt_2 = temperature change of the calorimeter cup and water, °C, and

ϕ = temperature correction, °C.

B. Indirect Method

The specific heat of a sample may also be calculated from the known values of bulk density thermal conductivity and thermal diffusivity for a particular variety of a crop at a specific moisture content by using the following equation:

$$c=\frac{k}{\rho\alpha} \qquad \ldots (7.2)$$

Where,

c = specific heat, cal/(g.°C)

k = thermal conductivity, cal/cm.s.°C

ρ = bulk density, g/cm^3, and

α= thermal diffusivity, cm^2/s.

Thermal Conductivity is defined as the amount of heat flow through unit thickness of material over an unit area per unit time for unit temperature difference.

The line source transient heat flow method can be used for determining the value of thermal conductivity, 'k'. The transient heat flow method developed orginally for measuring thermal conductivity of liquids (Lentz, 1952) has been successfully applied to measurement of thermal conductivity of a number of materials including grain (Kazarian and Hall, 1965; Wratten et al, 1969; Suter et al, 1975; Bilanski and Fisher, 1966). The apparatus for the determination of thermal conductivity, 'k' is shown in Fig. 7.1. The thermal conductivity is calculated by using the following equation :

$$K = \frac{q\ln(\varphi_2/\varphi_1)}{4\pi(t_2-t_1)} \qquad \ldots (7.3)$$

Where,

t_1 and t_2 are the temperatures of heating element at times φ_1 and φ_2, respectively and

q = heat input.

Thermal diffusivity is a quantity which measures the rate of temperature changes and indicates the speed at which temperature equilibriums will be reached. In order to calculate the temperature change in a grain bin due to fluctuations in external or internal temperature and to predict the heat transfer in the food grains, it is essential to determine thermal diffusivity of food grains.

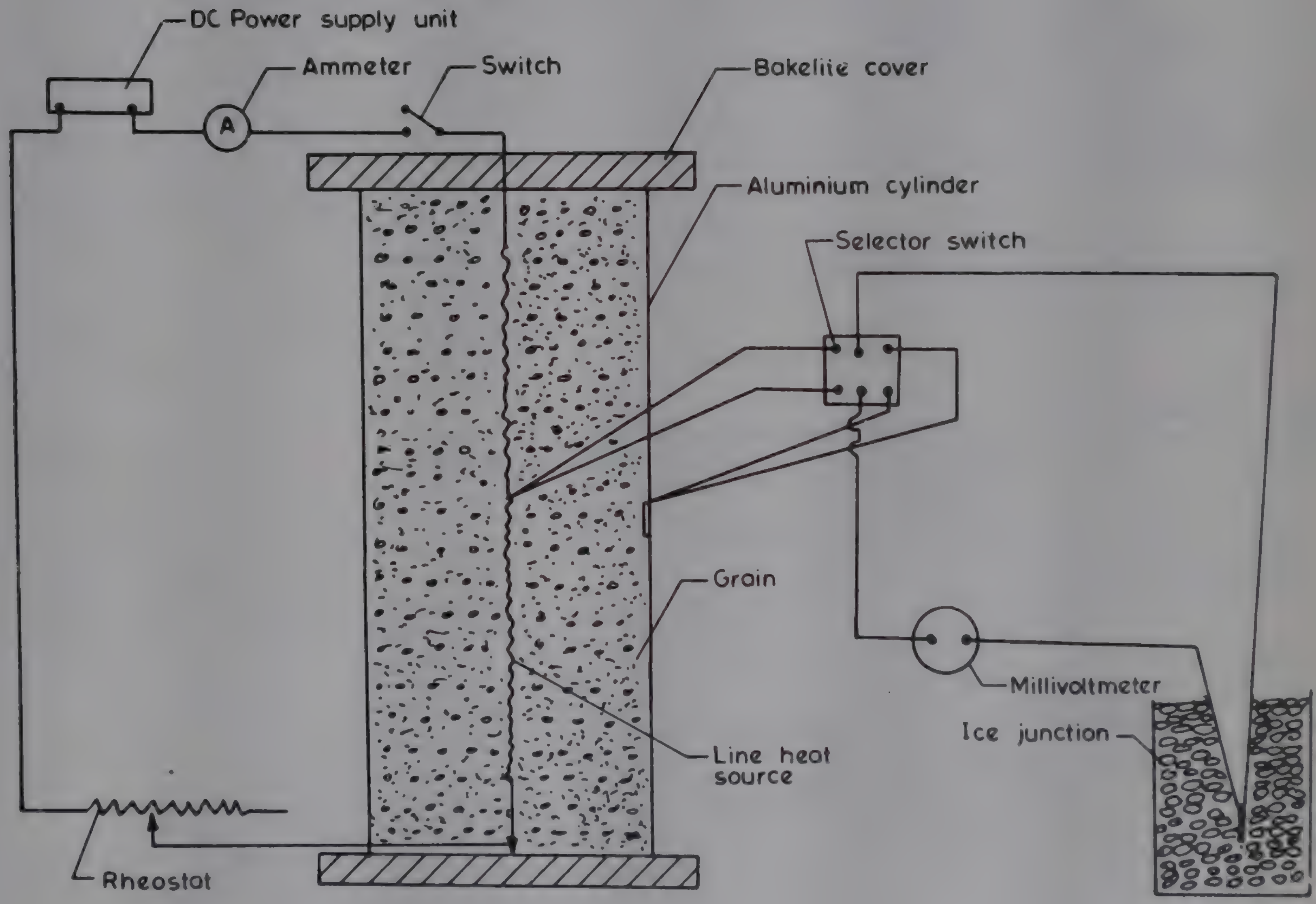


Fig. 7.1. Apparatus for the determination of thermal conductivity.

The following method may be used for the determination of thermal diffusivity of food grains (IS:10698-1983).

The apparatus consists of a thermal diffusivity tube and an insulated and well-stirred water bath of 25 litre capacity (Fig. 7.2).

Procedure

1. The food grain sample should be properly cleaned so that it does not have impurities more than 0.5 per cent. It should be free from insects, pests and micro-organisms.
2. Fill the cylinder (Fig. 7.2) with the food grains and place the entire assembly with end caps and thermocouples in a water bath. Heat the water bath at constant rate with the help of 1,000 W immersion heater. The output of the heater may be noted by connecting a wattmeter in the circuit. Stir the water in the tank with the help of a stirrer at suitable speed, driven by a motor of 40 W (1/20hp), 4,000 rpm and coupled to a speed regulator.

Calculation

Plot the temperature versus time curve for the center and the surface of the tube (Fig. 7.3) and calculate the thermal diffusivity by using the following formula:

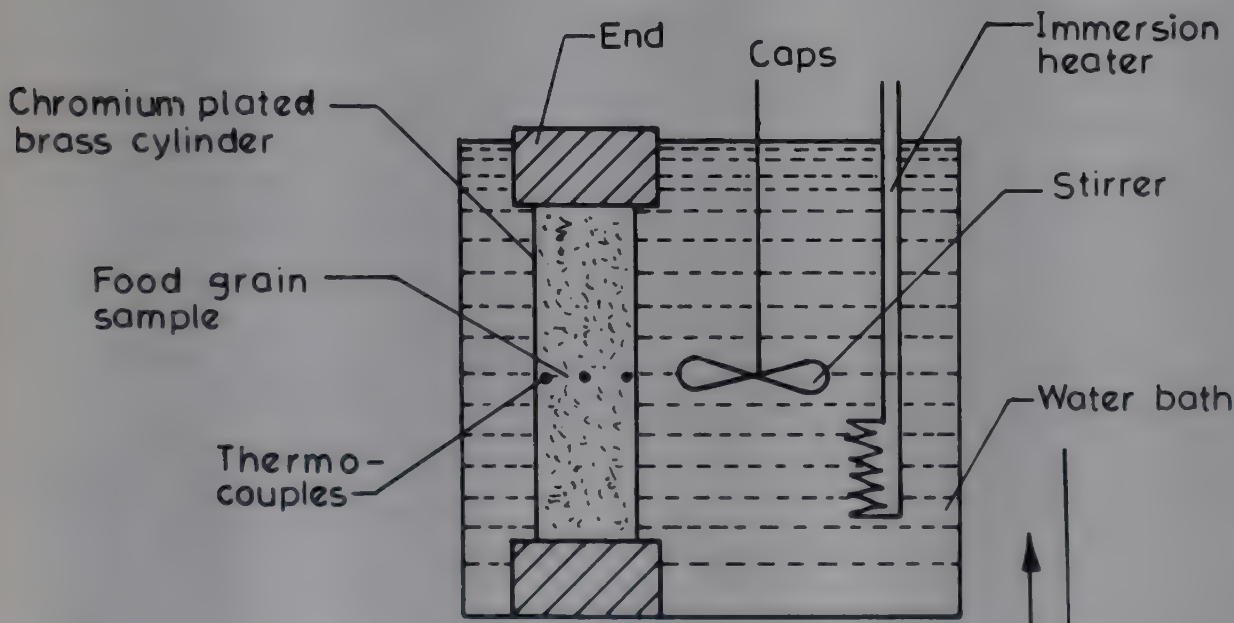


Fig. 7.2. Details of thermal diffusivity apparatus.

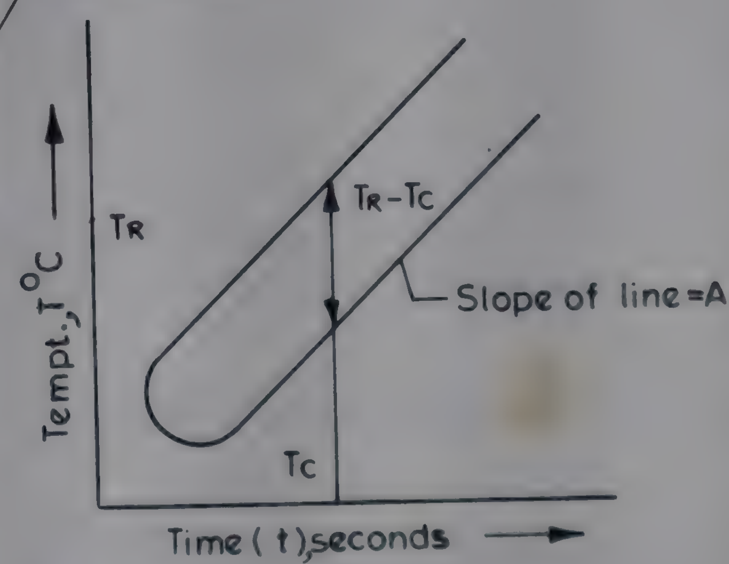


Fig. 7.3. Time-temperature curve.

$$\alpha = \frac{R^2 A}{4(T_R - T_C)} \quad \ldots (7.4)$$

Where,

α= Thermal diffusivity, cm^2/s

R = radius of the tube, cm

A = constant slope of temperature versus time curve in °C/s, and

$T_R - T_C$ = constant temperature difference at any time between temperature at the surface (T_R) and temperature at the center (T_C) of thermal diffusivity tube in °C (Fig. 7.3).

Various research workers have carried out studies on the thermal properties for cereals (maize, paddy, rice bran, sorghum and wheat), pulses (Bengal gram, black gram, green gram, lentil, pea and pigeon pea), oilseeds (castor, cotton seed, copra, groundnut, sesamum, soybean and sunflower) an jaggery (gur) for Indian varieties at different moisture contents. Some of these properties such as, thermal conductivity, specific heat and thermal diffusivity are listed in the Tables 7.1 - 7.4.

Table 7.1 : Thermal properties of cereals

Grain/Variety	Moisutre content, % (db)	Thermal conductivity, W/m. ^{0}C	Specific heat, J/g. ^{0}C	Thermal diffusivity, cm^2/s x 10^{-4}	Reference
1.	2.	3.	4.	5.	6.
Maize					36,41
Ganga—5	7.6	0.149	—	—	
	9.8	0.154	—	—	
	11.8	0.158	—	—	
	14.2	0.160	—	—	
	14.7	0.165	—	—	
	16.5	0.170	—	—	
	22.7	0.178	—	—	
Local	11.1	0.148	1.63	11.20	
	16.3	0.156	1.80	11.00	
	21.9	0.164	1.97	10.80	
	31.6	0.177	2.22	10.50	
Vijay	11.1	0.159	1.88	10.00	
	16.3	0.164	2.05	9.76	
	21.9	0.169	2.18	9.52	
	31.6	0.176	2.43	9.16	
Paddy					34,35,147
IR—8	10.7	0.150	—	—	
	16.4	0.161	—	—	
	21.7	0.171	—	—	
	28.2	0.177	—	—	
	31.2	0.183	—	—	
Jaya	11.1	0.117	1.42	9.60	
	16.3	0.123	1.59	8.80	
	21.9	0.129	1.76	8.00	
	31.6	0.138	2.01	6.80	
Jeshn— [illegible]	11.1	0.112	1.34	14.00	
	16.3	0.118	1.51	12.80	
	21.9	0.123	1.67	11.60	
	31.6	0.132	1.93	9.80	
Palmon—	11.1	0.108	1.30	9.60	
	16.3	0.114	1.47	8.80	
	21.9	0.120	1.63	8.00	
	31.6	0.129	1.88	6.80	
	9.8	0.085	—	—	
	18.0	0.110	—	—	
	28.7	0.140	—	—	
	34.6	0.120	—	—	

Fig. 7.2. Deta

Table Contd....

1.	2..	3.	4.	5.	6.
Rice bran	8.7—13.6	—	1.85	—	34,41
	11.1	0.164 (W/m. K)	0.413(cal/g.K)	0.777	
	13.6	0.192 (W/m.K)	0.429(cal/g.K)	0.876	
Sorghum					1,36
PSH—2	8.0	0.130	1.42	11.69	
	11.0	0.133	1.97	8.49	
	14.0	0.136	2.30	7.76	
	17.0	0.137	2.43	7.27	
	20.0	0.138	2.51	7.34	
Swarna	8.0	0.133	1.42	11.05	
	11.0	0.136	1.93	8.67	
	14.0	0.138	2.22	7.84	
	17.0	0.140	2.26	7.71	
	20.0	0.141	2.47	7.50	
Wheat					14,15,16
Ralyan—227	8.7	0.133	1.67	10.36	
	13.6	0.137	1.84	10.04	
	19.0	0.141	1.97	9.72	
	25.0	0.145	2.14	9.40	
	31.6	0.149	2.30	9.08	
Sonalika	9.1	0.321	—	—	
	11.1	0.335	—	—	
	13.6	0.370	—	—	
	16.3	0.377	—	—	
	19.0	0.423	—	—	
RR—21	8.6	0.299	—	—	
	11.1	0.329	—	—	
	13.6	0.361	—	—	
	16.3	0.392	—	—	
	19.0	0.423	—	—	
S—227	9.1	0.265	—	—	
	11.1	0.302	—	—	
	13.6	0.358	—	—	
	16.3	0.367	—	—	
	19.0	0.405	—	—	
WG—357	8.7	0.127	1.63	9.46	
	13.6	0.130	1.80	9.14	
	19.0	0.132	1.93	8.82	
	25.0	0.135	2.05	8.50	
	31.6	0.137	2.18	8.18	

Table 7.2 : Thermal properties of pulses

Grain/Variety	Moisuture content, % (db)	Specific heat, J/g. ^{0}C	Reference
1.	2.	3.	4.
Bengal gram			55
CS—24	7.5	1.72	
Black gram			55
T—9	13.6	1.88	
Green gram			55
Pb	7.5	1.84	
	13.6	1.97	
Lentil			55
L—9—12	13.6	1.93	
Pea			55
Arcle	13.6	2.01	
Pigeon pea			55
T—21	21.9	2.01	
	31.6	2.18	

Table 7.3 : Thermal properties of oilseeds

Seed/Variety	Moisture content, % (db)	Thermal conductivity, W/m. ^{0}C	Specific heat, J/g. ^{0}C	Thermal diffusivity, cm^2/s x 10^{-4}	Reference
1.	2.	3.	4.	5.	6.
Castor (kernel)					41
Local	8.7—13.6	—	1.97	—	
Castor (whole)					41
Local	8.7—13.6	—	1.67	—	
Cotton seed cake	8.7—13.6	—	1.88	—	
Cotton seed (meat)					41
Fuzzy	2.0	0.108	—	—	
	6.3	0.118	—	—	
	8.7—13.6	—	1.80	—	
Cotton seed (whole)					41
Fuzzy	8.7	0.077	—	—	
	8.7—13.6	—	1.76	—	
	13.6	0.079	—	—	
Copra					41
Local	8.7—13.6	—	1.76	—	
Groundnut cake	8.7—13.6	—	1.88	—	
Groundnut (kernel)					41
AK—12—24	8.0	0.097	1.76	7.24	
	11.0	0.100	2.18	6.82	
	14.0	0.106	2.26	6.34	
	17.0	0.108	2.43	6.10	

Table contd.....

1.	2.	3.	4.	5.	6.
	20.0	0.113	2.51	6.28	
Local	5.3	0.112	—	—	
	6.4	—	2.01	—	
	13.6	—	2.05	—	
SB—11	8.0	0.094	1.30	9.43	
	11.0	0.097	2.05	6.93	
	14.0	0.103	2.18	6.52	
	17.0	0.106	2.26	6.40	
	20.0	0.109	2.47	6.40	
Groundnut (pod)					41
Local	8.7—13.6	—	1.51	—	
Groundnut (shell)	8.7—13.6	—	1.63	—	41
Sesamum (decuticled)					41
Local	8.7—13.6	—	1.97	—	
Seasamum (whole)					41
Local	6.3	0.101	—	—	
	8.7—13.6	—	1.93	—	
	13.6	0.103	—	—	
Soybean					14,35
Bragg	2.9	0.246	—	—	
	13.9	0.286	—	—	
	19.3	0.303	—	—	
	25.3	0.320	—	—	
	29.0	0.328	—	—	
Hardee	9.5	0.170	—	—	
	11.0	0.172	—	—	
	13.0	0.175	—	—	
	15.0	0.177	—	—	
Local	8.7—13.6	—	0.40	—	
Sunflower (kernel)					41
Local	8.7—13.6	—	0.47	—	
Sunflower (whole)					41
Local	8.7—13.6	—	0.40	—	

Table 7.4 Thermal properties of jaggery (gur)

Material	Moisture content, % (db)	True density, kg/m^3	Thermal conductivity, W/m. °C	Specific heat, J/kg. °C	Thermal diffusivity, $cm^2/s \times 10^{-4}$	Reference
Jaggery (gur)	4.7	1350	0.0278	0.265	7.77	65
	6.2	1370	0.0298	0.274	7.95	
	7.4	1386	0.0326	0.279	8.44	
	8.4	1404	0.0396	0.302	9.33	
	9.9	1415	0.0428	0.311	9.73	
	11.7	1436	0.0458	0.317	10.13	
	12.4	1438	0.0485	0.320	10.52	
	13.8	1440	0.0512	0.327	10.83	

CHAPTER-VIII

HYGROSCOPIC PROPERTIES

Hygroscopictiy

The grain is a living organsim and hygroscopic in nature. It absorbs or desorbs moisture as temperature and relative humidity conditions change. A knowledge of hygroscopic behaviour of grains is essential because of its direct relationship to storage and drying problems. Every hygroscopic substance tends to maintain a certain vapour pressure at a given temperature and relative humidity. This vapour pressure is known as equilibrium vapour pressure and the corresponding moisture content is known as equilibrium moisture content. This hygroscopic moisture of grains is of major concern for the design of grain storage, packaging and drying units, estimation of storage life and reconditioning factors etc. In order to provide proper moisture conditions for a particular material, it is often necessary to add or to remove moisture from the material. An understanding of this wetting and drying process requires a knowledge of the Equilibrium Moisture Content (EMC) of the material for the environment to which it is subjected.

The EMC OF MATERIAL in a given environment is the mositure content which the material would approach if left in that environment for an infinite period of time. The relative humidity of the surrounding atmosphere at which material approaches hygroscopic equilibrium is known as Equilibrium Relative Humidity at a particular temperature.

The equilibrium moisture content is important from the point of view of:

a. ensuring whether the material will gain or lose moisture under given set of temperature and relative humidity conditions,

b. determining the rate of moisture removal, and

c. establishing a lower limit to which the material can be dried under known drying conditions.

The relationship between the mositure content of a particular material and its equilibrium relative humidity at a particular temperature can be expressed by means of a equilibrium moisture curves. These curves are sometimes referred to as ISOTHERMS because the values plotted for each curve usually corrospond to a specific temperature (Fig. 8.1).

The isotherm may be an ADSORPTION ISOTHERM which could be defined as a plot of equilibrium moisture content versus relative humidity at a given temperature for the material

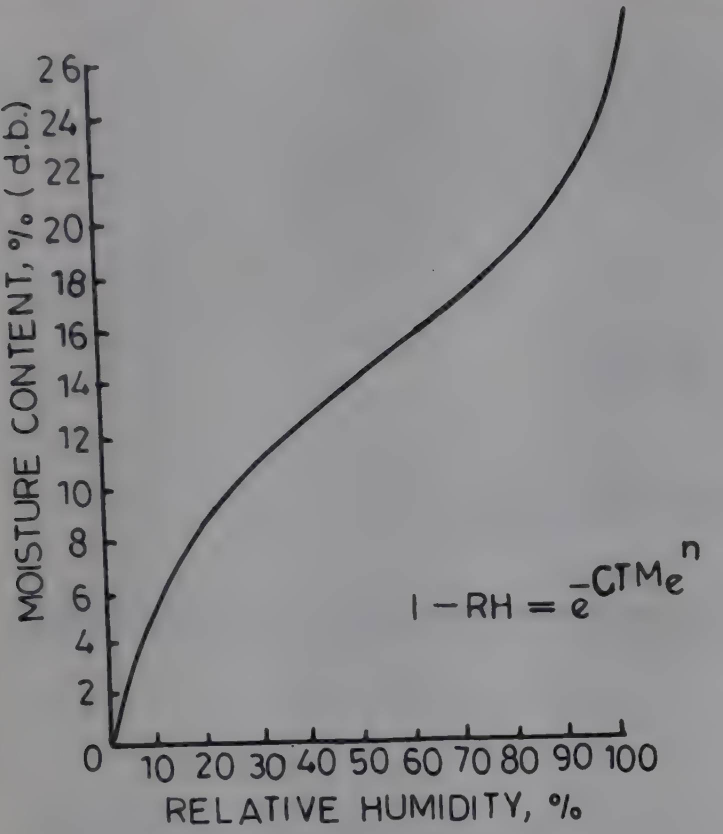


Fig. 8.1. Equilibrium moisture content curve for biological material

which has been subjected to a wetting environment while a DESORPTION ISOTHERM may be described as a plot of equilibrium moisture content versus relative humidity at a given temperature for a material which has been subjected to a drying environment.

An empirical equation (Henderson, 1952) relating temperature, relative humidity and equilibrium moisture content in biological materials is most often written as;

$$1 - RH = Exp.(-CTM_e^n) \qquad \ldots (8.1)$$

Where, RH = relative humidity, in decimal,

T = absolute temperature, K

M_e = equilibrium moisture content, % (db), and

C & n = constants varying with the material.

Sorption Hysteresis

The phenomenon of the non-coincidence of the adsorption and desorption isotherms is called sorption hysteresis. In other words, if equilibrium is sought from a low initial moisture through an adsorption process, the equilibrium moisutre value reached is not always the same as when equilibrium is sought from a high initial moisture through a desorption process.

Two theories, the 'open-pore' or 'delayed meniscus' theory' and the 'ink-bottle' or 'bottle-neck' or 'cavity theory' have explained the phenomenon of hysteresis. The basis of the cavity theory is the hypothesis that sorption occurs by a process of condensation in and evaporation out of capillaries which are distinguished from each other by their shape characteristics.

At each pressure, condensation will occur in those capillary regions with radii corresponding to that pressure. Similarly, in the case of 'bottle-neck' capillaries which have not been completely filled, desorption will be reverse of adsorption. In completely filled 'bottle-neck' capillaries, however, desorption will not occur until the vapour pressure of the system has been decreased to the value corresponding to pressure necessry to vapourize water under conditions at the neck. It is this effect which is responsible for hysteresis.

Determination of vapor pressure

The equilibrium moisture content information can be used for determining the vapor pressure of the material. If the vapor pressure of the material is higher than the vapor pressure of the surrounding atmosphere, moisture will, move from the material to the atmosphere. Conversely, if the vapor pressure of the material is lower than the surrounding atmosphere, moisture will move from the atmosphere to the material. The vapor pressure of the material can be determined by superimposing the equilibrium moisture content data on a psychrometric chart (Fig. 8.2).

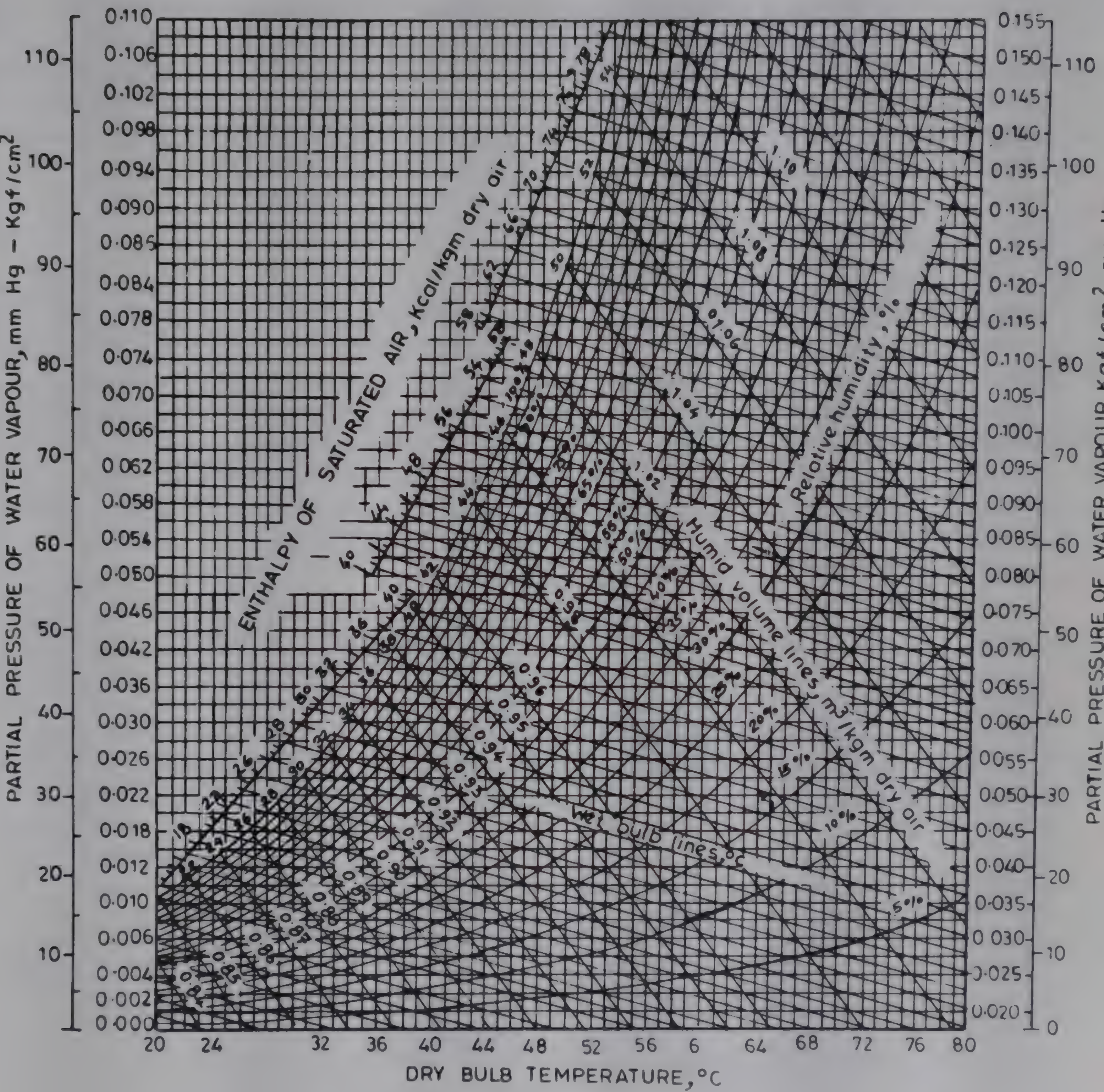


Fig. 8.2. Psychrometric Chart (Baromatric pressure 760 mm of Mercury) .

Determination of equilibrium moisture content

Two general methods are used for determining the equilibrium moisture content. The STATIC METHOD, in which atmosphere surrounding the product comes to equilibrium with the product without mechanical agitation of the air or product, and the DYNAMIC METHOD, in which the atmosphere surrounding the product or the product is mechanically moved. The dynamic method is quicker but presents problems in design and instrumentation. Therefore, the static method has been used more extensively. However, both the methods are described here. When the static method is used for determining the equilibrium moisture content, a saturated salt solution or an acid solution may be used for maintaining the desired relative humidities at different temperatures.

Static Method

For determining the equilibrium moisutre content of grains using static method, environmental chamber is to be built for controlling the temperature and relative humidity. For this, Kachru (1985) has developed an environmental chamber (Fig. 8.3), to study the hygroscopic equilibrium of rough rice in desorption. The chamber was made of using pressed wood with a thin metal sheet as inside lining. The metal sheet lining was used to eliminate the possiblity of moisutre exchange between the pressed wood and the inside environment.

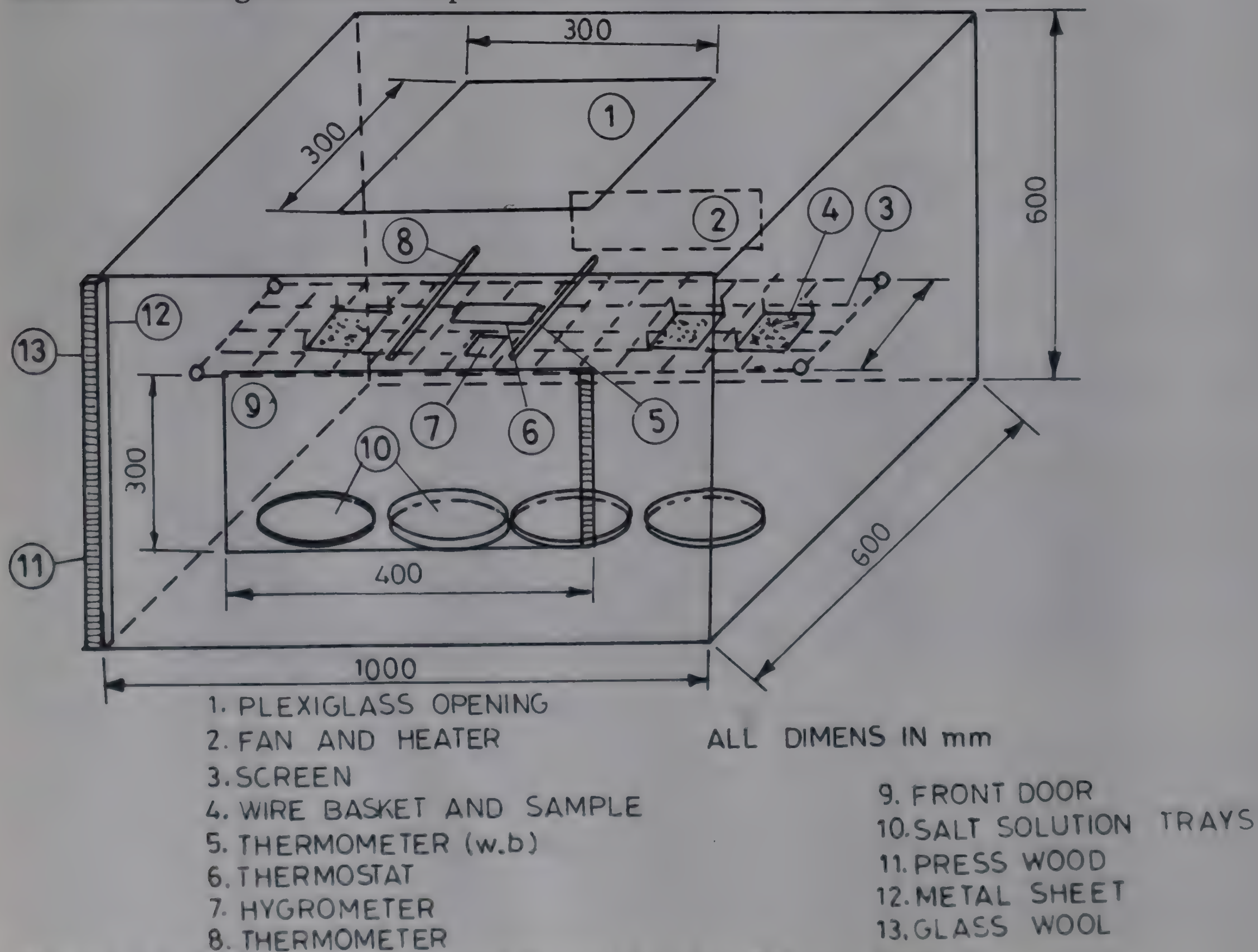


Fig. 8.3. Isometric view of an environmental chamber (Kachru, 1985).

The dimensions of the chamber were 0.6 m x 0.6 m x 1.0 m. The chamber was insulated by covering it with three layers of glass wool and kept air tight by using foam gaskets. A door was provided on the front side to have an access for checking the samples for weighing, taking dry and wet bulb temperatures and changing the salt solutions during the experimental runs.

At the top of the chamber, a sheet of plexiglass (0.3 m x 0.3 m) was provided for watching the inside of the chamber without disturbing the inside environment. A wire mesh floor was provided inside the chamber on which the samples, thermostat, thermometers and hygrometer were placed. A fancoil was hooked against the chamber wall having its 1000 W heater element connected to the thermostat through a red bulb alarm sign and a fan to agitate the inside air continuously. The experiments for the studies (Kachru, 1985) were arranged in such a way that higher temperature experiments were conducted in warmer season and vice-versa, because the chamber could not maintain the temperature below the surrounding. Different relative humidities were maintained by using known saturated salt solutions at different temperatures.

Tables 8.1 to 8.3 give the various salts and relative humidities achieved at different levels of temperature, weight of salt required to saturate 100 ml of water and different concentrations of aqueous acid solutions at various temperatures, respectively.

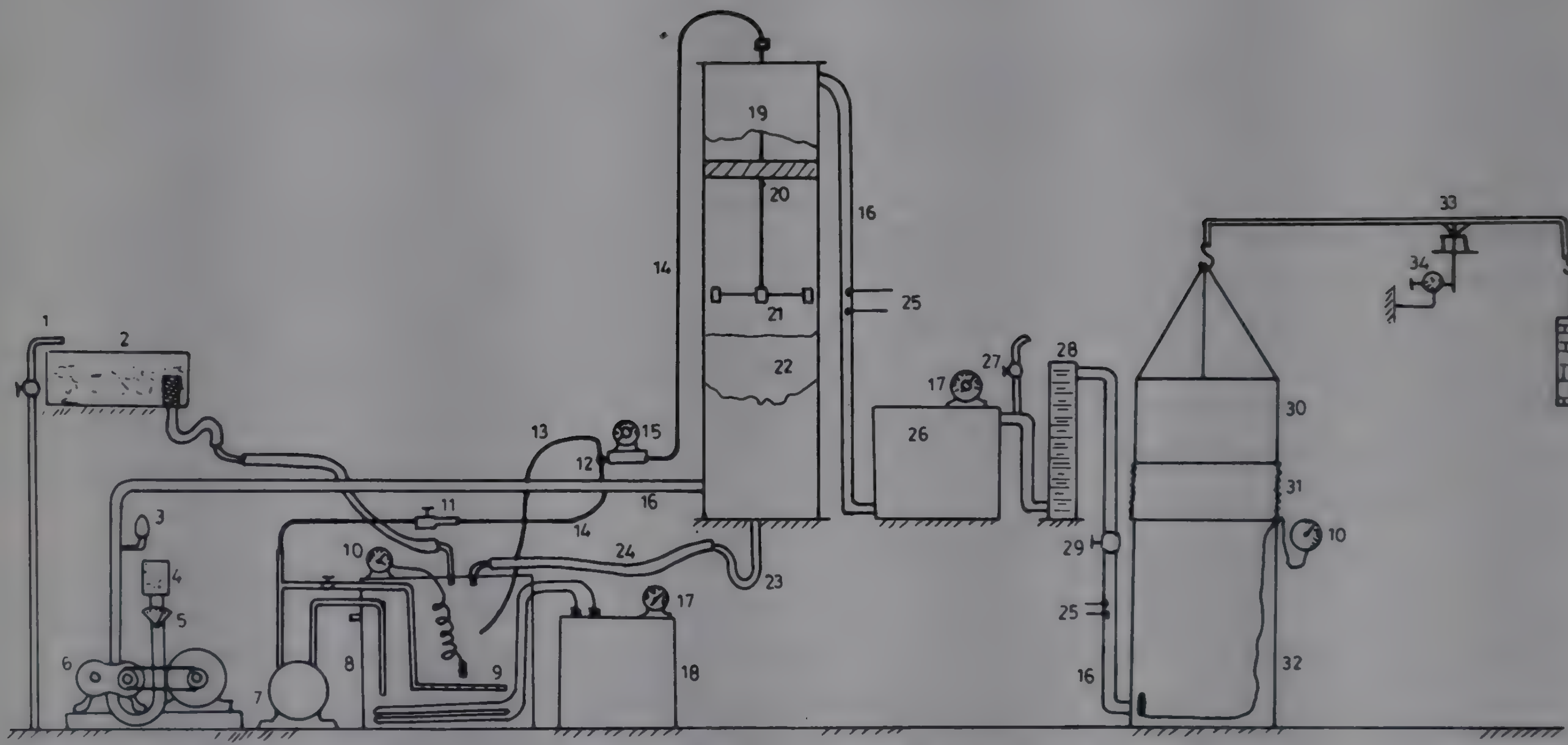
About 700-900 cc of salt solution was placed in the plastic trays (4 Nos.), kept inside the chamber and 4 to 5 g of dry salt was also added to the solutions to maintain their saturation condition. A simple hygrometer was used to monitor the relative humidity fluctuations. The order of changing the chemicals were selected in such a way that one set of experiments under constant temperature would begin from the highest relative humidity and endup with the lowest relative humidity for EMC studies in desorption. However, in adsorption, one set of experiments under constant temperature would begin from the lowest relative humdity and endup with the highest relative humidty.

The initial sample weight for EMC studies should be taken between 30–35 g, maintaining a thin layer of 1–3 kernels. An electronic balance with an accuracy of ± 0.0001 g is to be used for weighing the samples. When the weight of each sample had not changed for three subsequent turns (3-4 days interval), it is assumed that a sample has reached the equilibrium stage. At this point, 3-4 g sample is taken out and its moisture content is determined using standard method. This moisture content is the E.M.C. of the grains at a particular temperature and relative humidity.

Dynamic Method.

For determing the equilibrium moisutre content of grains using dynamic method, an experimental set-up is to be made in which the atmosphere surrounding the product or the product is mechanically moved. For this, Kachru (1969) has developed an experimental set-up, for determination of constants C and n used in the Henderson's formula on equilibrium moisutre content for paddy varieties. This set-up (Fig. 8.4) consists of air supplying unit, water cooling unit, air humidifying unit, air heating unit, grain drying unit and balancing unit.

Before the experimentation, the refrigerating unit was allowed to cool the water in the water tank to a desirable level (say about 20°C). To achieve the uniform temperature throughout the tank, the water was recirculated in the beginning by means of a by-pass pipe. The blower and the water pump were then started to send air and water to the humidifying chamber, respectively. The wet-bulb depression of the air was zero before entering the heating unit. The humidified air was made to pass through the thermostatically controlled heating unit (Fig. 8.4). This hot air in the beginning was diverted to the atmoshpere with the help of an valve



1. WATER SUPPLY OUTLET
2. WATER FILTER
3. SAFETY VALVE
4. AIR FILTER
5. AIR INLET CONTROL
6. BLOWER
7. PUMP
8. WATER TANK
9. WATER STIRRER
10. DIAL THERMOMETER
11. WATER FILTER AND VALVE
12. THREE WAY VALVE
13. BY PASS
14. PRESSURE PIPE (WATER)
15. PRESSURE GAUGE
16. AIR PIPE
17. THERMOSTAT SWITCH
18. WATER COOLING UNIT
19. SPRAY CHAMBER
20. WATER DROPLET FILTER
21. SPRAY NOZZLES
22. AUTOMIZER
23. WATER TRAP
24. EXCESS WATER OUTLET
25. WET/DRY-BULB THERMOMETERS
26. HEATER UNIT
27. CONTROL VALVE
28. ROTAMETER
29. CONTROL VALVE
30. GRAIN CHAMBER
31. FLEXIBLE CONNECTION
32. PLENUM CHAMBER
33. BALANCING BEAM
34. DIAL GAUGE INDICATOR

Fig. 8.4. The experimental set-up for determination of E. M. C., using dynamic method (Kachru, 1969)

arrangement, to attain constant temperature. During the time the air could achieve this stability, the paddy grains were put in the drying chamber, whose initial m.c. was known and made balanced with the help of placing dead weights on the other end of balancing unit. At this point, the dial gauge would indicate zero reading. The air at required constant temperature was then diverted to the drying chamber through a rotameter with the help of two valves. In the beginning, the pointer on the dial gauge would shift through some divisions due to the pressure exerted by the drying air. This was rectified by bringing the pointer to zero mark again. The time was noted as zero minute at that stage. Hereafter, readings were taken after every 10 minutes till the pointer maintained a static position. The whole drying and balancing unit was covered up to check the influence of the atmospheric air disturbance on dial gauge readings.

The experiments conducted would take 4 to 8 hours total to attain a constant weight of a sample, depending upon the initial moisture content, air temperature and its relative humidity. Once the weight of sample becomes constant, its moisture content is determined using standard method. This moisture content is the E.M.C. of the sample at a particular environment condition.

Various research workers have carried out studies on hygroscopic equilibrium for cereals (maize, paddy, wheat, wheat flour and wheat semolina 'suji'); pulses (Bengal gram, Bengal gram flour 'besan', lentil and pigeon pea) and oil seeds (groundnut, groundnut kernel, groundnut shell, mustard, soybean, soyflour 'defatted' and soyflour 'full fat'). The values of E.M.C. in adosrption and desorption of some food crops are listed in the Tables 8.4 to 8.6.

Table 8.1 : Relative humidity of saturated salt solution at different temperatures (Hall, 1957)

Salt	Tempt., ^0C	RH, %
1.	2.	3.
$BaCl_2 . 2H_2O$[38] (Barium chloride)	29	88.0
$CaCl_2$[37] (Calcium chloride)	0	41.0
	10	40.0
	21	35.0
$CaCl_2 . 6H_2O$ (Calcium chloride)	5	39.8
	20	32.3
	24	31.0
$CaSO_4 . 5H_2O$ (Calcium sulfate)	20	98.0
$Ca(No_3)_2$[37] (Calcium nitrate)	0	64.0
	10	59.0
	21	55.0
$Ca(NO_3)_2 . 4H_2O$[43] (Calcium nitrate)	20	53.6
	25	50.4
	30	46.6
	35	42.0
	38	38.9
KBr (Potassium bromide)	20	84.0
	100	69.2
$K_2CO_3 . 2H_2O$ (Potassium carbonate)	19	44.0
	24	43.0
KCNS[43] (Potassium thiocynate)	20	47.6
	25	45.7
	30	43.8
	38	41.1
$KC_2H_3O_2$[43] (Potassium acetate)	20	23.2
	25	22.7
	30	22.0
	38	20.4
KNO_2[43] (Potassium nitrite)	20	49.0
	25	48.2
	30	47.2
	38	45.9
KNO_3[40] (Potassium nitrate)	0	97.6
	10	95.5
	20	93.2
	30	90.7
	40	87.9
	50	85.0
K_2CO_3[43] (Potassium carbonate)	20	43.9
	25	43.8
	30	43.6
	38	43.4
K_2CrO_4[43] (Potassium chromate)	20	86.6
	25	86.5
	30	86.3
	38	85.6

Table Contd...

1.	2.	3.
K_2SO_4[40] (Potassium sulfate)	0	99.1
	10	97.9
	20	97.2
	30	96.6
	40	96.2
	50	95.8
$LiCl.H_2O$[40] (Lithium chloride)	0	14.7
	20	12.4
	30	11.8
	40	11.6
	50	11.4
$LiCl$[43] (Lithium chloride)	20	11.2
	25	11.2
	30	11.2
	38	11.2
$MgCl_2$[42] (Magnesium chloride)	23	32.9
	30	32.4
	38	31.9
$MgCl_2 . 6H_2O$[40] (Magnesium chloride)	0	35.0
	20	33.6
	30	32.8
	40	32.1
	50	31.4
$Mg(NO_3)_2$[42] (Magnesium nitrate)	23	53.5
	30	51.4
	38	49.0
$Mg(NO_3)_2 . 6H_2O$[40] (Magnesium nitrate)	0	60.6
	20	54.9
	30	52.0
	40	49.2
	50	46.3
$NaBr$[43] (Sodium bromide)	20	59.2
	25	57.8
	30	56.3
	38	53.7
$NaCl$[40,43] (Sodium chloride)	0	74.9
	20	75.5
	30	75.6
	40	75.4
	50	74.7
$NaC_2H_3O_2$[42] (Sodium acetate)	23	74.8
	30	71.4
	38	67.7
$NaC_2H_3O_2 . 3H_2O$[43] (Sodium acetate)	20	76.0
	25	73.7
	30	71.3
	38	67.6
$NaNO_2$[42,43] (Sodium nitrite)	20	65.3
	25	64.3
	30	63.3
	38	61.8

Table Contd...

1.	2.	3.
$Na_2Cr_2O_7$[42] (Sodium dichromate)	23	54.1
	30	52.0
	38	50.0
$Na_2Cr_2O_7 \cdot 2H_2O$[40] (Sodium dichromate)	0	60.6
	20	55.2
	30	52.5
	40	49.8
	50	46.3
NH_4Cl[37] (Ammonium chloride)	0	83.0
	10	81.0
	21	75.0
$NH_4H_2PO_4$[43] (Ammonium Monophosphate)	20	93.2
	25	92.6
	30	92.0
	38	91.1
$(NH_4)_2SO_4$[40,43] (Ammonium sulfate)	0	83.7
	20	80.6
	30	80.0
	40	79.6
	50	79.1

Table 8.2 : Weight of salt required to saturate 100 ml of water (Hall, 1957)

Chemical	Tempt., °C	Weight, g
$BaCl_2 . 2H_20$[29] (Barium chloride)	0	39.3
	100	76.8
$CaCl_2$[29] (Calcium chloride)	0	59.5
	20	74.5
	30	102.0
$CoCl$[22] (Cobaltous chloride)	7	45.0
	96	105.0
$CuCl_2 . 2H_2O$ (Cupric chloride)	0	110.4
	100	192.4
KCL[29] Potassium chloride)	20	34.0
	30	37.0
	40	40.0
KNO_3[29] (Potassium nitrate)	20	31.6
	30	45.8
	40	63.9
K_2CrO_4[29] (Potassium chromate)	20	61.7
	30	63.4
	40	65.2
K_2SO_3[29] (Potassium sulfate)	20	11.11
	30	12.97
	40	14.76
$LiCl$[22] (Lithium chloride)	100	127.5
$LiCl . H_2O$[32] (Lithium chloride)	30	46.3
	44	48.3
	90	54.8
$MgCl_2$ (Magnesium chloride)	0	52.8
	38	73.0
$MgCl_2 .6H_2O$[29]	0	281.0
	100	918.0
$NaCl$[29] (Sodium chloride)	10	35.8
	20	36.0
	30	36.3
	40	36.6
	100	39.1
$NaNO_2$ (Sodium nitrite)	0	72.0
	100	163.0

Table 8.3 : Relative humidity of different concentrations of aqueous acid solutions at various temperatures, per cent (Hall, 1957)

Acid	Tempt., °C	Acid by weight, per cent			
		20	40	60	80
H_2SO_4 (Sulfuric)	10	87.4	56.6	15.8	3.88
	20	87.7	56.7	16.3	4.76
	30	87.5	56.6	17.0	5.75
	40	87.6	57.5	17.8	6.88
	44	88.8	58.2	18.8	8.20
		Acid by weight, per cent			
		20	30	40	50
HNO_3 (Nitric)	10	86.7	77.0	63.0	45.6
	20	86.6	75.2	61.5	
	30	86.6	74.9	61.3	
	40	85.9	74.1	60.5	
	44	86.5	74.6		
	60	86.9	75.6		
		Acid by weight, per cent			
		10	20	30	40
HCL (Hydrochloric)	10	83.5			
	20	83.2			
	30	84.2			

Table 8.4 : See on page 138

Table 8.5 : Hygroscopicity of pulses

Grain/ Variety	Adsorption			Co-efficients in Henderson's equation*			Reference
	Tempt; °C	R.H., %	E.M.C., % (db)	C	n	R^2	
1.	2.	3.	4.	5.	6.	7.	8.
Bengal gram Radey	20	50.0	7.99				55
		70.0	9.29				
	30	50.0	6.48				
	50	65.0	7.45				
Bengal gram flour 'besan'	20	33.0	10.43	3.131395	1.643150	0.988	41,[illegible]
		43.9	12.09				
		54.2	14.62				
		59.6	15.90				
		68.4	19.66				
		79.2	21.84				
		90.7	30.61				
	30	32.4	8.77	4.653297	1.542517	0.995	
		43.5	11.23				
		51.4	12.65				
		69.4	17.82				
		78.2	20.43				
		89.9	28.10				

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.
	40	31.8	7.47	7.364640	1.414487	0.991	
		41.0	9.22				
		48.5	10.73				
		61.6	14.17				
		71.5	16.48				
		79.2	19.38				
		89.1	26.81				
	50	31.2	7.17	6.787346	1.481422	0.984	
		38.2	7.85				
		48.5	9.61				
		63.2	12.37				
		68.6	13.73				
		78.5	17.33				
		88.3	23.95				
Lentil L—9—12	20	50.0	9.11				55
		70.0	10.36				
	30	50.0	5.90				
	50	65.0	6.92				
Pegeonpea T—21	35	20.0	4.52				14,35
		45.0	7.89				
		65.0	10.86				
		75.0	13.06				
	70	20.0	3.57				
		45.0	5.51				
		65.0	10.23				
		75.0	13.51				
Local	43	10.49	2.36				
		31.48	—				
		42.00	3.62				
		60..50	5.63				
		74.85	8.56				
	50	10.38	2.16				
		30.59	6.49				
		40.6	3.11				
		60.25	4.90				
		75.13	6.56				
		86.7	13.38				

* $1\text{-}RH = e^{-CT} M_e^n$

Where,

RH = relative humidity, decimal; T = temperature, K

M_e = equilibrium moisture content, % (db), and C,n = co-efficients.

Table 8.4 : Hygroscopicity of cereals

Grain/ Variety	Adsorption			Desorption			Coefficients in Henderson's equation			Reference
	Temperature, °C	R.H., %	E.M.C., %(db)	Temperature, °C	R.H., %	E.M.C., % (db)	$C \times 10^{-5}$	n	R^2	
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Paddy				20	84.0	22.34	0.619603	2.254577	0.998	35,71,73
Champa					79.5	19.61				
					69.0	18.51				
					48.0	13.43				
					35.0	11.13				
					18.0	8.35				
				30	83.0	19.67	0.956142	2.127630	0.994	
					75.5	18.45				
					68.0	16.44				
					40.0	11.94				
					32.0	10.16				
					14.0	6.21				
				40	80.0	17.32	0.896370	2.202570	0.990	
					72.5	16.76				
					63.5	13.85				
					38.5	10.54				
					20.0	9.18				
					13.0	5.71				
Dular				48.5	21.5	13.95	1.3495×10^{-2}	3.27631	—	
					27.4	15.14				
					31.2	15.85				
					44.0	18.20				
				60.0	13.0	8.96	2.22703×10^{-2}	3.44183	—	
					18.0	9.89				
					23.0	10.64				
					26.0	11.26				

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
				70.0	9.0	6.49	1.55008×10^{-2}	3.99937		
					11.5	6.92				
					14.5	7.37				
					16.5	7.64				
IR–8				50.0	24.7	11.75	1.13022×10^{-5}	6.44320		
					29.0	12.06				
					36.0	12.59				
					42.2	13.0				
				61.0	12.0	8.67	5.50326×10^{-4}	7.28870		
					17.0	9.16				
					19.0	9.33				
					25.0	9.68				
				70.0	8.0	6.67	9.1097×10^{-7}	9.03388		
					11.0	6.85				
					15.0	7.15				
					17.0	7.27				
Jaya	20	20.0	8.84	20	80.0	20.45				
		45.0	14.30		75.0	17.92				
		65.0	18.78		65.0	14.27				
		75.0	21.52		45.0	10.53				
		80.0	24.75		20.0	5.79				
	35	20.0	10.74	35	80.0	20.48				
		45.0	14.69		75.0	18.16				
		65.0	18.22		45.0	12.31				
		75.0	20.64		20.0	9.46				
		80.0	21.71		—	—				
	50	20.0	7.34	50	80.0	16.24				
		45.0	12.37		75.0	15.98				
		65.0	15.81		65.0	13.33				

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
		75.0	17.62		45.0	9.87				
		80.0	19.29		20.0	5.89				
	70	20.0	8.67	70	80.0	14.36				
		45.0	12.07		75.0	15.35				
		65.0	14.05		65.0	11.10				
		75.0	18.08		45.0	9.18				
		80.0	18.05		20.0	6.19				
Patnai-23				46.5	27.0	12.00	2.78316×10^{-7}	7.92151	—	
					30.0	12.20				
					33.0	12.36				
					37.0	12.60				
				60.0	12.0	8.76	1.51149×10^{-6}	7.85681	—	
					18.5	9.30				
					20.0	9.40				
					26.0	9.77				
				70.00	8.5	6.98	2.96735×10^{-7}	9.41291	—	
					11.0	7.18				
					14.0	7.37				
					16.3	7.52				
Rashti Domsorkh				20	87.0	22.43	0.769133	2.184995	0.992	
					79.5	19.10				
					70.0	18.25				
					49.0	13.62				
					35.0	11.31				
					18.0	7.78				
				30	84.0	18.82	0.896480	2.203690	0.997	
					79.0	17.61				
					68.0	15.91				
					42.0	11.13				
					39.0	10.03				
					14.0	6.08				

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
				40	80.0	18.12	1.265132	2.088985	0.980	
					77.0	16.46				
					67.0	14.02				
					40.5	10.94				
					30.0	8.93				
					13.5	5.52				
Rashti Salari				20	89.5	21.04	0.393947	2.499090	0.994	
					82.5	18.23				
					75.0	16.84				
					48.0	13.24				
					36.0	10.62				
					18.0	7.84				
				30	83.0	18.19	0.010317	2.157080	0.992	
					79.0	18.01				
					70.0	15.56				
					38.5	10.99				
					32.0	9.56				
					15.0	6.01				
				40	80.0	18.02	0.095085	2.158205	0.994	
					77.0	15.97				
					67.0	14.23				
					40.0	10.48				
					30.0	8.45				
					14.0	5.81				
Taichung Native-1				50.0	15.0	10.33	1.18787×10^{-5}	6.53506	—	
					20.0	10.85				
					25.0	11.27				
					28.0	11.50				

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
				60.0	10.0	8.39	1.05802×10^{-5}	7.00666		
					16.0	9.04				
					25.0	9.68				
					30.0	10.00				
				68.0	10.0	7.21	1.41773×10^{-5}	7.38240		
					15.0	7.67				
					24.0	8.22				
					28.0	8.41				
Maize	43	10.49	1.13							14
Local		31.48	5.47							
		42.00	—							
		60.50	5.29							
		74.85	7.75							
	50	10.38	1.04							
		30.59	6.20							
		40.60	—							
		60.25	5.08							
		75.13	8.64							
		86.70	18.23							
Wheat	20	20.0	6.92	20	80.0	19.75				35
RR-21		45.0	11.84		75.0	17.18				
		65.0	15.87		65.0	13.19				
		75.0	18.58		45.0	9.71				
		80.0	21.27		20.0	6.42				
		90.0	29.12	35	45.0	7.94				
					20.0	5.32				
	35	65.0	12.83	50	80.0	16.12				
					75.0	14.67				
	50	20.0	5.29		65.0	11.36				
		45.0	10.27		45.0	9.05				
		65.0	12.56		20.0	5.41				
		75.0	13.96	70	65.0	10.18				

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
		80.0	17.48		45.0	6.71				
		90.0	40.55		20.0	3.41				
Wheat Flour	20	33.00	12.26				0.343746	2.379166	0.994	41,120
		39.00	14.12							
		55.00	16.89							
		65.35	18.98							
		75.20	21.46							
		85.00	23.56							
		90.70	25.53							
	30	29.25	10.53				0.448887	2.338708	0.991	
		43.50	12.59							
		51.35	15.59							
		63.20	17.20							
		74.40	19.56							
		83.40	20.92							
		89.90	23.69							
	40	31.80	8.75				1.905157	1.931582	0.995	
		43.90	10.20							
		49.65	11.89							
		61.55	13.95							
		71.50	16.00							
		81.70	18.85							
		89.10	21.15							

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
	50	31.20	6.70				4.871995	1.610424	0.991	
		38.20	8.71							
		46.95	10.31							
		68.60	14.63							
		82.20	17.33							
		88.30	20.83							
Wheat, Semolina 'Suji'	20	33.00	13.39				0.279829	2.414804	0.983	41,120
		39.00	14.35							
		54.24	16.75							
		59.60	17.83							
		68.40	19.70							
		79.20	22.03							
		90.70	28.73							
	30	29.25	12.98				0.276435	2.428147	0.984	
		32.40	14.63							
		43.50	16.04							
		51.35	18.25							
		63.20	19.36							
		74.40	21.24							
		89.90	27.44							
	40	31.80	12.08				0.386734	2.363688	0.965	
		41.00	13.08							
		48.45	13.77							
		61.55	16.90							
		71.50	17.88							
		79.15	20.11							
		89.10	25.91							

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
	50	31.20	10.75				5.571696	2.284325	0.960	
		38.20	11.91							
		45.50	12.35							
		63.20	15.34							
		68.60	16.31							
		78.45	18.11							
		88.30	24.49							

* $1\text{-}RH = e^{-CT} M_e^n$

Where,

RH = relative humidity, decimal,

T = temperature, K,

M_e = equilibrium moisture content, %(db), and

C, n = co-efficients.

Table 8.6 : Hygroscopicity of oil seeds

Grain/ Variety	Adsorption			Desorption			Co-efficients in Henderson's equation			Reference
	Temp., °C	R.H., %	E.M.C., %(db)	Temp., °C	R.H., %	E.M.C. %(db)	$C x 10^{-5}$	n	R^2	
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Groundnut (pod)	40	33.0	7.80	40	30.0	4.40	12.70 (adsorption)	1.48 (adsorption)		41
		40.0	8.90		40.0	5.60	3.19 (desorption)	1.80 (desorption)		
		50.0	10.60		50.0	6.90	—	—		
	45	30.0	6.80	45	30.0	3.50	22.50 (adsorption)	1.30 (adsorption)		
		40.0	8.40		40.0	4.40	5.44 (adsorption)	1.60 (adsorption)		
		50.	10.30		50.0	5.80	—	—		
	50	30.0	6.20	50	30.0	3.04	32.50 (adsorption)	1.11 (adsorption)		
		40.0	8.00		45.0	4.77	6.66 (desorption)	1.53 (desorption)		
		50.0	6.60		60.0	7.00	—	—		
Groundnut (kernel)				40	33.0	6.00	11.20 (desorption)	1.36 (desorption)		
					40.0	7.18				
					44.0	9.00				

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
				45	30.0	5.20	12.80 (desorption)	1.32 (desorption)		
					40.0	6.70				
					50.0	8.60				
				50	30.0	4.70	14.10 (desorption)	1.34 (desorption)		
					40.0	6.10				
					44.0	6.66				
Groundnut (shell)				40	33.0	9.10	4.44 (desorption)	1.52 (desorption)		41
					40.0	10.70				
					50.0	13.10				
				45	30.0	7.40	8.20 (desorption)	1.31 (desorption)		
					40.0	9.80				
					50.0	12.30				
				50	30.0	6.80	1.01 (desorption)	1.26 (desorption)		
					40.0	8.50				
					44.0	9.88				
Mustard	43	10.49	1.28							14
		31.48	3.62							
		42.00	—							
		60.50	3.80							

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
		74.85	5.85							
	50	10.38	1.23							
		30.59	4.30							
		40.60	—							
		60.25	3.69							
		75.13	5.90							
		86.70	10.50							
Soybean	20	43.9	6.52	20	85.0	25.05				14,41
		52.0	7.49		75.0	16.99				
		65.3	10.85		65.3	12.20				
		75.0	15.05		52.0	8.55				
		85.0	24.50		43.9	8.07				
	35	43.5	5.61	35	75.0	12.25				
		54.0	7.55		72.2	11.68				
		62.0	9.52		62.0	8.09				
		72.2	12.65		54.0	7.95				
		75.0	13.75		43.5	6.23				
	43	10.49	1.84							
		31.48	3.22							
		42.00	6.11							
		60.50	8.25							
		74.85	10.27							
	50	31.4	6.68	50	80.00	16.10				
		45.0	5.71		75.00	11.33				
		65.0	10.23		65.00	10.76				
		75.0	13.50		45.00	6.60				
		80.0	16.87		31.40	6.72				
	70	43.0	4.41	70	80.0	13.19				

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
		65.7	8.71		75.00	11.81				
		75.0	12.17		65.70	8.79				
		80.0	11.03		43.00	4.81				
Soyflour (defatted)	20	33.0	8.66				6.809781	1.407461	0.997	41,120
		39.0	9.85							
		54.2	13.11							
		59.6	14.90							
		68.4	17.51							
		79.2	22.09							
		90.7	30.78							
	30	32.4	7.68				9.665134	1.322522	0.987	
		43.5	9.04							
		51.4	11.06							
		63.2	13.45							
		69.4	16.15							
		78.2	20.50							
		89.9	28.06							
	40	31.8	6.55				12.639877	1.270602	0.994	
		41.0	7.48							
		48.5	8.85							
		61.6	11.90							
		71.5	15.18							
		81.7	19.05							
		89.1	24.78							
	50	31.2	5.56				14.030346	1.262732	0.994	
		38.2	6.41							
		45.5	7.59							

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
		63.2	11.82							
		68.6	12.39							
		79.2	16.17							
		88.3	22.28							
Soyflour (fullfat)	20	33.0	7.90				10.781814	1.285611	0.984	41,120
		43.9	9.22							
		54.2	11.75							
		59.6	13.07							
		68.4	15.35							
		79.2	21.53							
		90.7	30.36							
	30	32.4	6.32				14.039838	1.227063	0.994	
		43.5	8.50							
		51.4	9.66							
		63.2	12.36							
		69.4	14.94							
		78.2	18.42							
		89.9	26.91							
	40	31.8	5.85				14.482447	1.263091	0.972	
		41.0	7.12							
		48.5	7.93							
		61.6	10.90							
		71.5	12.25							
		79.2	16.05							
		89.1	24..80							
	50	31.2	5.29				15.687940	1.261158	0.970	
		38.2	6.15							

Table Contd....

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
		45.5	6.87							
		63.2	9.64							
		68.6	10.72							
		78.5	15.09							
		88.3	22.08							

* $1\text{-}RH = e^{-CT} M_e^{n}$

Where,

RH = relative humidity, decimal,

T = temperature, K,

M_e = equilibrium moisture content, % (db), and

C, n = co-efficients.

REFERENCES CITED

1. Adhaoo, S.H.; S.V.Dhawale and S.T.Ingle. Engineering properties of groundnut and jowar, part 2-Thermal properties. J. of Agril. Engg. 13(1) 1976. pp : 22-3.
2. Agrawal, Y.C.; A.K.Tikkoo; B.P.N.Singh and Maharaj Narain. Post harvest technology of oil seeds, Problems and perspectives. Bulletin of Grain Technol. 26(2) 1988, pp : 99-108.
3. Agricultural statistics at a glance. Directorate of Economics & Statistics, Department of Agriculture & Cooperation. Ministry of Agriculture, GOI, May 1992.
4. Alam, A and G.C.Shove. Hygroscopicity and thermal properties of soybean. Trans. ASAE 1973, 16(4), pp:707-9.
5. Alam, A and G.C.Shove. Hysteresis associated with hygroscopicity of soybeans. JAE, 12(1), 1975, pp:6-9.
6. Ali, M.H.; A.M.M.D. Rahman and M.J.Ullah. Effect of plant population and nitrogen on yield and oil content of rapeseed (Brassica napus). Indian J. of Agril. Sci. 60(9) 1990, pp : 624- 30.
7. Aniche, Georgeana N, and Hilary Nwokedi. Preliminary studies on the effect of drying temperature and time on the concentration of dimethyl sulphide in sorghum wort. J. of Food Sci. Technol. 27(1) 1990, pp : 13-4.
8. Annual Report. AICRP on Post Harvest Technology (ICAR), PKV, Akola, 1992.
9. Annual Report. AICRP on Post Harvest Technology (ICAR). CIAE, Bhopal, 1987, 1988.
10. Annual Report. AICRP on Post Harvest Technology (ICAR). TNAU, Coimbatore, 1973, 1974.
11. Annual Report. AICRP on Post Harvest Technology (ICAR), TNAU, Coimbatore, 1992.
12. Annual Report. AICRP on Post Harvest Technology (ICAR). AAU, Jorhat, 1989-90.
13. Annual Report. AICRP on Post Harvest Technology (ICAR). IIT, Kharagpur, 1972-73.
14. Annual Report. GBPUAT, Pantnagar, 1968-69.
15. Annual Report. AICRP on Post Harvest Technology (ICAR). GBPUAT, Pantnagar, 1972, 1973, 1974, 1977, 1978.
16. Annual Report. AICRP on Post Harvest Technology (ICAR). RAU, Udaipur, 1973, 1975.
17. Anon. Engineering characteristics of biological materials. Research Bull., Department of Processing and Agricultural Structures, PAU, Ludhiana, 1975.

18 Anon. Physical, chemical and milling characteristics of baragu (common millet) varieties. Mysore. J. of Agril. Sciences. 1993.

19. Anuradha, K and P.S. Sarma. Potassium for yield improvement of sorghum (sorghum bicolor). Indian J. of Agril. Sci. 60(9) 1990, pp : 634-5.
20. Arora, S. and V.B. Sehgal. Effect of moisture content on the physical properties of oil seeds., J. of Agril. Engg. 24(3), 1987. pp ; 279-85.

21. Balu, B.Venkanna; T.Ramana and T.M.Radhakrishnan. Chemical composition and protein content in hybrid varieties of fingermillet. Indian J. of Agril. Sci. 57(7) 1987, pp : 520-1.

22. Bargale, P.C.Development and testing of manual flax scutching machine. Biological Wastes, 32(1990), pp : 29-37.

23. Bhat. K. Shama; S.Bhagavan and R.V.Nair. Identification of high yielding trees in cacao (Theobroma Cacao). Indian J. of Agril. Sc. 60(9) 1990, pp : 641-2.

24. Bhat, S.S.; G.N.Kulkarni and B.K.Ramachandrappa. Response of pigeonpea genotypes to different dates of sowing. Madras. Agric. J. 76(7) 1989, pp : 413-6.

25. Bist, H.S. and S.D.Sharma. Vegetative characters of some local cultivars of grape (Vitis species) grown in Kinnaur. Indian J. of Agril. Sc. 60(9) 1990, pp : 636-7.

26. Brubaker. J.E. and J.Pos. Determining static coefficient of friction of grains on structural surfaces. Trans. ASAE, 1965, 8(1), pp : 53-5.

27. Carl, W. Hall. Drying of Farm Crops, Lyall Book Depot; Ludhiana, 1970.

28. Chakravarty A. and D.S.De. Post harvest technology of cereals and pulses. Oxford and IBH Publishing Co. 1981.

29. Chattopadyay, P.K.; Premchand; T.C.Mishra and N.D.Patil. Pneumatic separator for various rice fractions. Agril. Mechanization in Asia, Africa and Latin America. 14(3) 1983, pp : 49-54.

30. Chauhan, B.M.; Neeraj Suneja and C.M.Bhat. Nutritional value and fatty acid composition of some high yielding varieties of bajra. Bulletin of Grain Technol. 24(1) 1986, pp : 44-9.

31. Choudhary, B.S.; R.R.Rawat and S.C.Pathak. Relative preference of calloso bruchus chinensis (LINN) for differnet varieties of green gram. Bulletin of Grain Technology. 27(2) 1989, pp : 107- 12.

32. Choudhary, B.S. and S.C.Pathak. Relative preference of calloso-bruchus chinensis (LINN) for different varieties of Bengal gram. Bulletin of Grain Technology. 27(3) 1989, pp : 181-7.

33. Decade of Post Harvest Technology (1975-86). AICRP on Post Harvest Technology (ICAR). TNAU, Coimbatore.

34. Decade of Post Harvest Technology (1972-79). AICRP on Post Harvest Technology (ICAR). IIT, Kharagpur.

35. Decade of Post Harvest Technology (1972-79). AICRP on Post Harvest Technology (ICAR). GBPUAT, Pantnagar.

36. Decade of Post Harvest Technology (1972-82). AICRP on Post Harvest Technology (ICAR). RAU, Udaipur.

37. Deshpande, S.D.; S. Bal and T. P. Ojha. Physical properties of soybean. J. Agric. Engng. Res. 56 (2) 1993, pp : 89–98.

38. Dev, D.K.; P.N.Satwadhar and V.M.Ingle. Effect of variety and moisture on certain selected physical properties of sorghum grain. J. of Agril. Engg., 19(2) 1982, pp : 43-7.

39. Dharmalingam, V. and M.Kadamba Vana Sundaram. Genetic divergence in cowpea. Madras Agric. J. 76(7), 1989. pp : 394-9.

40. Dutta, S.K.; V.K.Nema and R.K.Bhardwaj. Thermal properties of gram. J.Agri.Engng. Res. 39(4), 1988, pp : 269-75.

41. Engineering properties of food materials (Tech. Bull. CIAE/80/15), PHTS, CIAE, Bhopal. 1980. (Compiled : Singh, BPN; P.C. Sah and A.K. Tikoo. Edited and Illustrated : Alam, A.)

42. Fraser, B.M.; S.S.Verma and W.M.Muir. Some physical properties of fababeans. J.Agri.Engng. Res. 23(1), 1978, pp : 53-7.

43. Gadekar, Prema; D.B.Dhumale and R.S.Raut. Inter relationship between yield and its components in rice bean (Vigna Umbillata). Indian J. of Agril. Sc. 60(8) 1990, pp : 547-9.

44. Ghosh, B.N.Physical properties and processing of Arabia coffee beans. J. of Agril. Engng. 3(1) 1966, pp : 30-4.

45. Girija, T. and N.Natarajaratnam. Green matter yield and dry matter accumulation trends in forage sorghum cultivators. Madras, Agricultural J. 76(5) 1989, pp : 261-5.

46. Gopalkrishanan, M.; C.S.Narayanan, D. Kumaresan and P.Bhaskaran. Physico-Chemical changes in cardamom infested with trips. Spice India. 2(12) Dec. 1988, pp : 18-21.

47. Gopalan, C; B.V.Ramasastri and S.C.Balsubramanian. Nutritive value of Indian foods. National Institue of Nutrition, ICMR, Hyderabad, 1982.

48. Grover, P.C. and Deepak Kumar. Some engineering properties of pulses. Proc. of ISAE, SJC 1985, vol. 3, pp : II-27-35.

49. Gupta R.K. and R.P. Kachru. Physical, aerodynamic and rheological properties of aniseed. Paper submitted for publication in 'Spice India'. 1992.

50. Gupta, R.K. and R.P. Kachru. Physical properties of turmeric rhyzomes and powder. Spice India. Vol. V. No. 10. Oct. 1992, pp : 7-8 and 14.

51. Gupta, R.K. and R.P. Kachru. Some selected engineering properties of castor seed. CIAE, Bhopal 1993.

52. Gupta, R.K. and Saurab Prakash. Effect of moisture content on some engineering properties of pulses. Paper presented at XXVI Annual Conv. of ISAE held at Hissar, during 7-9 Feb. 1990.

53. Gupta, R.K.; Saurabh Prakash and B.D.Shukla, Effect of moisture content on physical properties of groundnut. Paper presented at XXIV Annual Convention of ISAE held at Akola, during 21-23 Jan. 1988.

54. Gupta, R.K.; Saurabh Prakash and B.D.Shukla. Effect of moisture content on some engineering properties of castor. Paper presented at XXV Annual Conv. of ISAE held at Udaipur, during Jan. 5-7,1989.

55. Gupta, R.K. and Saurabh Prakash. Studies on physical, aerodynamic, rheological, thermal and biological properties of oilseeds and pulses. Final report (RPF-III), CIAE, Bhopal, 1991.

56. Gupta, Subhash; J.L.Srivastava and B.K.Verma. Studies on the absorption of moisture by different food grains at different relative humidities. Bulletin of Grain Technology. 18(2) 1980, pp : 165-7.

57. Hand book of Agriculture. ICAR. 1984, pp : 1268-71.

58. Holkar, Sunil; K.N.Ruwali and B.H.Matai. Growth and yield responses of some improved and land race wheat varieties under rainfed conditions. Indian J. of Plant Physiology. XXXII(2) 1989, pp : 188-93.

59. Ibrahim, S. Mohamad and N.Gopalasamy. Effect of age of seedling on growth and yield of transplanted maize. Madras Agric. J. 76(4) 1989, pp : 181-3.

60. Indian Standard, IS : 4333 Part III, 1967. Methods of analysis for food grains.

61. Indian Standard, IS : 4333 Part IV, 1968. Methods of analysis for food grains. Weight of 1000 grains.

62. Indian Standard, IS ; 6663-1972. Method for determination of angle of repose of grains.

63. Indian Standard; IS ; 10698-1983. Method for determination of thermal diffusivity of food grains.

64. Indain Standard, IS : 10699, 1983. Method for determination of specific heat of food grains.

65. Information received through correspondance from AICRP on Post Harvest Technology Centres of PKV, Akola; UAS, Bangalore; TNAU, Coimbatore; JNKVV, Jabalpur; AAU, Jorhat; GAU, Jaunagadh; GBPUAT, Pantnagar and CTCRI, Trivandrum.

66. Jain, P. C., Sharma, M. P. and Rajesh Kumar. An investigation on thermal properties of gur (jaggery). Indian Journal of Agril. Engg. 2 (1) March 1992, pp : 71–3.

67. Jain, V.K.; Y.S.Chauhan; M.P.Khandekar and P.C.Jain. Effect of sowing dates and genotypes on yield and yield attributing traits in Indian mustard. Madras Agricultural J. 76(5) 1989, pp : 241-6.

68. Jana, P.K.; A.Barik; S.Ghatak; A.K.Mukherjee and G.Sanuda. Effect of nitrogen, phosphorus and potassium on yield and yield attributes of rainfed groundnut (Arach is hypogaea). Indian J. of Agril. Sc. 60(1) 1990, pp : 49-51.

69. Jeena, H.S. and S.C.Mani. Evaluation of rice (Oryza Sativa) genotypes for rainfed upland. Indian J. of Agril. Sc. 60(5) 1990, pp : 340-1.

70. Jha, S.N. and Suresh Prasad. Physical and mechanical properties of gorgon nut. Paper presented at XXVIII Annual Convention of ISAE held at CIAE, Bhopal, during March 2-4, 1993.

71. Kachru, R.P. Determination of constants C and n used in the Henderson's formula on equilibrium moisture content for paddy varieties. Unpublished. M.Tech. Thesis, IIT, Kharagpur, 1969.

72. Kachru, R.P.Development of niger seed separator. Part-I, Some physical properties of various fractions in niger seed stock. Proc. of ISAE, SJC; Process, Food and Diary Engg; Vol : 3, pp : II, 62-6, 1985.

73. Kachru, R.P.Hygroscopic equilbrium of rough rice in desorption at 20°, 30° and 40°C. Journal of the Institution of Engineers (India). Agril. Engg. Division. Vol. 65, AG. 1-2, pp : 8- 11, 1985.

74. Kachru, R.P. Statics and Kinetics of rough rice drying. Unpulished Ph.D. Dissertation, Mississippi State University, USA. 1972.

75. Kachru, R.P. and D. R. Rai. Physical constituents and some engineering properties of peanut pods. Jr. of Oilseeds Res. 10 (2) 1993.

76. Kachru, R.P. and K.M.Sahay. Development and testing of manual grain screen cleaner. Paper presented at National Conference on Recent Trends in Processing of Cereals, Pulses and Oilseeds, held at PHTC, IIT,Kharagpur, during Dec. 18-20, 1984.

77. Kachru. R.P. and K.M.Sahay. Development and testing of pedal- cum-power operated air screen grain cleaner. AMA, Vol : 21, No. 4. 1990. pp : 29-32.

78. Kachru, R.P. and K.M. Sahay. Separation of oilseeds by pedal- cum-power operated air screen cleaner. J. of Oilseeds Research. Vol.5, No. 2, 1988, pp : 132-9.

79. Kachru, R.P. and P.K. Srivastava. Post harvest technology of ginger. Ginger special 'Cardamom'. Vol. 20, No. 5, May 1988, pp : 49-57.

80. Kachru, R.P. and P.K.Srivastava, Potential of rural based agro-processing industries in Punjab for higher economic gains and better employment generation. Agricultural Engg. Today. Vol. 13, No. 5 and 6, 1989, pp : 35-45.

81. Kachru, R.P. and P.K.Srivastava. Status of chilli processing. Part I. Spice India. Vol. III, No. 1, Jan. 1990, pp : 13-6.

82. Kachru, R.P. and P.K. Srivastava. Status of chilli processing. Part II. Spice India. Vol III, No. 2, Feb. 1990, pp : 10-5.

83. Kachru, R.P. and P.K. Srivastava and R.T. Patil. Post harvest aspects of cardamom. Cardamom. Vol.21, No.6, 1988, pp: 7-16.

84. Kachru, R.P.; P.K. Srivastava and R.T. Patil. Post harvest operations for tree spices. Part I. Spice India. Vol.II, No.11, Nov. 1989. pp: 5-8.

85. Kachru, R.P.; P.K. Srivastava and R.T. Patil. Post harvest operations for tree spices. Part II. Spice India. Vol. II, No.12, Dec.1989, pp: 13-7.

86. Kachru, R. P. and R. K. Gupta. Some selected engineering properties of coriander seed and powder. Paper presented at XXVIII Annual Convention of ISAE held at CIAE, Bhopal during March 2-4, 1993.

87. Kachru, R.P. and R.K. Matthes. The behaviour of rough rice in sorption. J.Agri. Engng. Res. 1976, 21, pp : 405-16.

88. Kachru, R.P., R.T. Patil and P.K. Srivastava. Post harvest operations of minor spices. Spice India. Vol.III, No.12, Dec.1990, pp: 13-9.

89. Kachru, R.P., R.T. Patil and P.K. Srivastava. Post harvest technology of pepper. Spice India. Vol. III, No.8, Aug.1990, pp:12-6.

90. Kachru, R.P., T.P. Ojha and G.T.Kurup. Drying characteristics of Indian paddy varieties. Grain Technology. Vol.8, No.3, 1970, pp:98-102.

91. Kachru, R.P., T.P. Ojha, and G.T.Kurup. Equilibrium moisture content of Indian paddy varieties. Grain Technology. Vol.9, No.3, 1971,pp: 186-96.

92. Kahar, L.S. and K.B. Nigam. Response of opium poppy (Papavor Somniferum) to phosphorus and potassium. Indian J. of Agril. Sc. 60(6) 1990, pp: 417-8.

93. Kalavathi, D and K.Vanangamudi. Seed size, seedling vigour and storability in cluster beans. Madras Agric. J. 77(1) 1990, pp: 39-40.

94. Kar, C; B. Barua and K. Gupta. Responses of the safflower plant (Carthamur tinctorius L.Cv. JLA 900) towards plant growth retardants dikegulac sodium. CCC and Sadh. Indian J. of Plant Physiology. XXXII (2) 1989, pp: 144-7.

95. Katiyar, S.K.; K. Sharma; N. Kumar and A.K. Bhatia. Composition of some unconventional himalayan wild fruits. J.Fd. Sc. Technol. 27(5) 1990, pp: 309-10.

96. Kazarian,E.A. and C.W. Hall. Thermal properties of grains. Trans. ASAE. 1965, 8(1), pp: 33-37, 48.

97. Khanday, B.A. and R.C. Thakur. Response of rainfed maize (zea mays) to fertilization. Indian J. of Agril. Sc. 60(9) 1990, pp: 631-3.

98. Kumar, B.M.; M. Mahadevappa; P.V. Subbarao and H.S.R. Desikachar. Relationship of the courseness of rice (Oryza Sativa) varieties to the thickness of bran and aleuron layers. J.of Food Science and Tech. 5, 1968, pp: 193-4.

99. Kumar, Virendar and S.K. Agarwal. Influence of irrigation and nitrogen levels on growth and yield in huskless barley (Hordium vulgare), Indian J. of Agril.Sci. 60(9) 1990, pp: 596-600.

100. Kushwah, V.S. and J.S. Grewal. Relative performance of cut and whole seed turbers for growth and yield of potato (Solonum tuberosum). Indian J. of Agril. Sci. 60(5) 1990, pp:321-7.

101. Lorenzen, C. Moisture effect on granular friction of small grains. Trans. ASAE, 1959, Paper No. 59-416.

102. Mahapatra, P.K.;D.Satpathy; U.N. Dikshit and S.K. Uttaray. Effect of raw ratios in sesame (Sesamum indicum) and pigeonpea (Cajanas Cajan) intercropping. Indian J. of Agril. Sci. 60(6) 1990, pp: 419-21.

103. Maheshwari, R.C. and T.P. Ojha. Fuel characteristics of rice husk. Paper presented at XII ISAE Conv. 1974, OAT, Bhubaneshwar, India.

104. Majumdar, K. L. High capacity multi-crop thresher. RPF–III. CIAE, Bhopal. 1993.

105. Manivasakam, P.; N. Jayaraman; M.N. Prasad; T.S. Ravendran and S.Palanisamy, A new high yielding composite cumbu (Pearl millet Pennisetum americanum L.Leeke) for Tamil Nadu. Madras Agricultural J. 76(5) 1989, pp: 270-5.

106. Md.Nural Islam and T.T. Pedresen. Some physical properties of wheat and paddy and their relationship. AMA. 1987. 18(1), pp: 45-50.

107. Misra, Arvind; K. Mohan Naidu and M.L. Gupta. Effect of raw spacing and nitrogen level on ethanol production in sugarcane (Sacchareim officinarum) at different ages of crop harvest. Indian J. of Agril. Sc.60(2) 1990, pp: 110-4.

108. Mohsenin, Nuri N. Physical properties of food and agricultural materials. Gorden and Breach Science Publishers, Inc., One Park Avenue, New York, 1980.

109. Mohsenin, Nuri N. Physical properties of food and agricultural materials, a teaching manual. Gorden and Breach Science Publishers, Inc. One Park Avenue, New York, 1981.

110. Murthy, T.S.N; B.N Rao; and K. Kumna Rao. Physical properties of paddy grains. J. of Agril. Engg. 23(4) 1986 pp: 368-71.

111. Nagaraj, G. Biochemical quality of oilseeds. J. of Oilseed Research, 7(1) 1990, pp: 47-55.

112. Nagra, S.S. and J.S. Chawla. Cereals : as alternate energy sources for maize. Poultry Guide. XXV (7) 1988, pp: 17-20.

113. Naravani, N.B. and J.S. Panwar. A study on the physical and engineering properties of sunflower related to threshing. Part of unpublished Ph.D. thesis. Div. of Agril. Engg, IARI, New Delhi, 1991.

114. Natarajan, N. and P.C. Sundra Babu. Effect of sorghum earhead bag infestation on seed quality. Bulletin of grain Technol. 26(1) 1988, pp: 64-70.

115. Nath, V. and S.N. Bhardwaj. Regulation of seed size by plant hormones in field pea (Pisum satirum linn var a Arvensis). Indian J. of Plant Physiology. XXXII(2) 1989, pp: 178-81.

116. Nigam, K.B; V.S. Kandalkar and D.B. Dhumale. Induced mutants in opium poppy (Papaver somniferum). Indian J. of Agril. Sc. 60(4) 1990, pp: 267-8.

117. Paliwal, S.C. and Gurumukh Singh. Physico-chemical milling and bread making quality of wheats of Uttar Pradesh. J. Fd. Sc.Technol. 23(4) 1986, pp: 189-93.

118. Papli, Sarla and Kuldip Singh Dhindra. Quality characteristics of improved wheat varieties of Haryana and Punjab. Bulletin of Grain Technology. XVIII(1) 1980, pp: 10-6.

119. Prakash, S; M.C. Nautiyal and A. Kumar. Effect of plant growth substances and chemical on fruit retention and quality of 'Tesia Samisto' peach (Prunur persica). Indian J. of Agril. Sc. 60(6) 1990, pp: 387-91.

120. Pratap, V. Equilibrium moisture content of some flours. Unpublished M. Tech. Thesis, GBPUAT, Pantnagar, 1979.

121. Purohit, A.G. Effect of pollen parent on seed hardness in pomegranate. Indian. J. of Agril. Sc. 57(10) 1987, pp: 753-5.

122. Qadar, Ali. Differential Sodicity tolerance of growth and yield parameters in genotypes of rice (Oryza sativa). Indian J. of Agril. Sc. 58(8) 1988, pp: 607-11.

123. Raghuwanshi, R.K.S; V.K. Paradkar and R.K. Gupta. Effect of phosphorus levels and seed rate on yield of linseed grown in sodic clay soil. Indian J. of Agril. Sc. 57(2) 1987, pp: 948-9.

124. Rahim, A; C.N. Vatrala; G.Venkateswara Rao and S.R. Shurpalekar. A small scale process for milling of wheat, Part-II. A process for coarse grit (Dalia) milling. J.Fd. Sc. Technol. 23(4) 1986, pp: 193-6.

125. Rai, Bhupendra. Oil from sunflower. Kheti, Feb. 1988, pp: 10-3.

126. Raina, B.L.; A.K. Bhatia; S.K. Katiyar and A.K. Gupta. Quality characteristics of promising Himachal alive varieties of apple (alea evropaea L.) J. of Fd. Sc. Techno. 23(4) 1986, pp: 237-9.

127. Ramakrishna, P. Melon seeds-evaluation of physical characteristics. J. of Food Sc. Technol. 23(3) 1986, pp: 158-60.

128. Rao, K. Sundar and K.Singh. Chemical composition of newer oilseeds. The J. of the Oil Tech. Assoc. of India. XXII (3) 1990, pp: 56-7.

129. Rao, N. Kameshwara; Melak H. Mengesha and R.P.S. Pundir.. Cleavage damage due to rapid drying in pea-shaped seeds of chickpea (Cicer arietinum). Indian J. of Agril. Sc. 60(4) 1990, pp: 255-8.

130. Rao, S.D. and K.B. Bhattacharya. Some physical properties of rice with special reference to waxy and Ballu varieties. CFTRI, Mysore, 1977.

131. Reddy, B.B; S.N. Reddy; V.M.Reddy; M.R.Reddy; A.Kumar and K.B.Swamy. Effect of plant populations on the performance of maize hybrids at different fertility levels in a semi-arid environment. Indian J. of Agril. Sc. 57(10) 1987, pp: 705-9.

132. Renu and Leena Bhattacharya. Proximate composition of improved genotypes of peas (Pisum sotivrum). Bulletin of Grain Technol. 27(2) 1989, pp: 118-23.

133. Saha, Anita and D.K.Das Gupta. Physiological attributes of elite cultures of rice (Oryza sativa) under water logged condition. Indian J. of Agril. Sc. 60(6) 1990, pp: 428-30.

134. Saikia, L and G.S.Bains. Studies of some Assam rice varieties for processing and nutritional quality. J. of Food. Sc. Tech. 27(5) 1990, pp: 345-8.

135. Saini, S.K; J.N.Singh and P.C.Gupta. Effect of threshing methods on seed quality of soyabean. Bulletin of Grain Technology. 18(2) 1980, pp: 105-10.

136. Sangwan, Naresh K; Braham S.Verma; T.R.Ahlawat and Kuldip Singh Dhindsa. Varietal differences in quality characters of rice. Bulletin of Grain Technology. 27(3) 1989, pp: 208-16.

137. Satasiya, R.M; J.N.Nandasana and A.L. Varshney. Effect of moisture content on physical characteristics and properties of peanut pods. Paper presented at XXVIII Annual Convention of ISAE held at CIAE, Bhopal, during March 2-4, 1993.

138. Satyanarayana, K.V; R.Lakshminarayana and R.B.Narayana. Yield improvement in Indian flue-cured tobacco. Indian J. of Agril. Sc. 55(11) 1985, pp: 674-9.

139. Satyanarayan, M. Influence of corn weight on growth and yield of basrai banana. Madras Agric. J. 76(8) 1989, pp: 464-6.

140. Sawhney, Balwinder and B.L.Kawatra. Supplimentary value of beet (Beta vulgaris), Knol-Khol (Brassica cleracea) and Turnip (Brassica rapa) greens on the protein quality of wheat chapati. J.Fd. Sc. Technol. 23(6) 1986, pp: 311-5.

141. Sethi, P.S. and H.S. Brar. Processing and marketing of honey in Punjab. Paper presented at XXVIII Annual Conv. of ISAE held a CIAE, Bhopal, during March 2-4, 1993.

142. Sethi, P.S; P.C. Grover and B.C.Thakur. Selected engineering properties of raya, toria and gobisarson. Paper presented at XXVI Annual Convention of ISAE held at HAU, Hissar during 7-9, Feb. 1990.

143. Sharma, S.K; R.K. Dubey and C.K.Techchandani. Engineering properties of black gram, soybean and green gram. Proc. of ISAE, SJC Vol.3, 1985 : II, pp : 181-5.

144. Sharma, U.C. Effect of sources and methods of nitrogen application on yield and nitrogen uptake of potato (Solonum tuberosum) in Meghalaya. Indian J. of Agril. Sc. 60(2) 1990, pp: 119-22.

145. Shashidhara, S.P. Steady flow of grain air mixture in horizontal pipes. Unpublished M. Tech. Thesis, GBPUAT, Pantnagar. 1971

146. Shepherd, H and R.K. Bhardwaj. Moisture dependent physical properties of pigeonpea. J. Agri. Engng. Res. 35, 1986, pp: 227- 34.

147. Sheriff, J.T. Determination of physical and thermal properties of biological materials. Unpublished B.E. (Ag.) Thesis. TNAU, Coimbatore, 1984.

148. Sheriff, J.T. Final Report submitted for his training at CIAE, Bhopal. Jan-July 1990.

149. Sheriff, N.Mohamed. Relative contribution of intra capitular regions on the seed yield in sunflower. Madras Agric. J. 76(4) 1989, pp: 825-6.

150. Shingari, B.K; B.K.Gupta and S.Sappo. Feeding value of gullidanda seeds in broiler diets. Poultry Guide. XXV (7) 1988, pp: 21-5.

151. Shrivastava, A.K; B.Panda and N.Darshan. Comparative nutritive values of different cereals in quail diets. Indian J. of Animal Sc. 60(6) 1990, pp: 720-4.

152. Sidhu, M.S; B.D.Sharma and J.S.Saulhney. Grain yield of wheat (Triticum aestivum) and changes in available nutrient status as affected by different fodders grown in rotation and N rates in sandy loam soil. Indian J. of Agril. Sc. 60(5) 1990, pp: 312-6.

153. Singh, Ashok. Factors affecting characteristics of egg shell and shell membranes. Poultry Guide. XXVII (9) 1990, pp: 65-9.

154. Singh, B.P.N; D.K.Gupta and R.R.Lal. Thermal conductivity of wheat. Paper presented at XII ISAE Conv. 1974, OAT, Bhubaheshwar, India.

155. Singh, Gurmukh and S.C.Paliwal. Physico-chemical milling and bread making quality of two varieties of duram wheats. Bulletin of Grain Technol. 24(1) 1986, pp: 73-6.

156. Singh, Harlier; H.C.Sharma; A.C.Malik; Tej Singh and A.S.Paroda. Effect of soil moisture regimes on seed yield, water use and water use efficiency of rapeseed (Brassica Napus). Indian. J. of Agril. Sci. 60(1) 1990, pp: 45-8.

157. Singh, Harpal. A study of pressure drop in pneumatic conveying of rice husk. Unpublished Ph.D. Dissertation. AIT, Bangkok, Thailand, 1990.

158. Singh, Kamla and V.C.Sharma. Response of potato (Solonum tuberasum) cultivars to phosphorus in acidic soils of Meghalaya. Indian J. of Agril. Sc. 58(8) 1988, pp: 600-2.

159. Singh, M.K; R.L. Pandey and A.K.Tripathi. Performance of niger in northern hill region of chhattisgarh. Indian J. of Agril. Sc. 57(12) 1987, pp: 950-1.

160. Singh, Neelam; M.S.Usha and G.S. Chauhan. Evaluation of some U.P. hill wheats for their physical, chemical, rheological and bread making characteristics. J.Fd. Sc. Technol. 27(4) 1990, pp: 198- 201.

161. Singh, Phundan and S.S.Narayanan. Interracial introgression for some economic characters in Gassypium arboreum linn. Indian J. of of Agril. Sc. 57 (9) 1987, pp : 628-30.

162. Singh, R.P. and Arvind Kumar. Effect of varieties and planting geometry levels on late sown Indian mustard (Brassica Juncea). Indian J. of Agril. Sc. 60(6) 1990, pp: 392-5.

163. Siwasamy, S. Terminal velocity of solids. Unpublished M.Tech. Thesis. GBPUAT, Pantnagar, 1971.

164. Sood, D.R. Comparison of quality characters of basmati-510 and mutant HK_2R_{21} varieties of rice. Bulletin of Grain Technol. 27(1) 1989, pp: 52-3.

165. Sreenarayanan, V.V; V.Subramaniyan and R.Visvanathan. Physical and thermal properties of soybean. Proc. of ISAE SJC 1985, Vol. 3, pp: II-161-9.

166. Srivastava, P.K. Determination of physical, thermal and chemical properties of rice bran in relation to its handling, storage and stabilization. Unpublished M.Tech. Thesis, 1976. IIT, Kharagpur.

167. Srivastava, S; D.P.Mishra and B.P.Khare. Effect of insect infestation on biochemical composition of pigeon pea (Cajanas Cajan L) seeds stored in mud bin. Bulletin of Grain Technol. 26(2) 1988. pp: 120-5.

168. Subramaniam, V; P. Thenammai and A.Dakshinamurthy. Physical characteristics of paddy variety. Jr. of Agric. Engng., XIV. No. 2. 1977, pp : 81-8.

169. Sudhakar, T. Ratna; K.Sreeramamurthy and P.V.Narayanarao. Relative susceptibility of jowar varieties to rice weevil (Sitophilus oryzae linn). Bulletin of Grain Technol. 26(3` 1988, pp: 208-13.

170. Summerfield, R. J. and E. H. Roberts. Grain Legume Crops. Collins, 8 Grafton Street, London WI. 1985.

171. Taware S. P; G. B. Halvankar; V. M. Raut and V.P. Patil. Hybrid vigour in soybean (Glycine max). Indian J. of Agril. Sc. 60(8) 1990, pp : 545-6.

172. Technical informations, PHTS, CIAE, BhopaL, 1992.

173. Technical informations received from various centres of AICRP on Post Harvest Technology (ICAR). 1992.

174. Test Report on CIAE multicrop thresher, TT&TS. Budni, M.P. June 1990.

175. Thirumalarao, S.D; R.Raghuramarao and B.R. Reddy. Varietal corelation between different quality components in mustard. J. of Oil Tech. Assoc. of India, 4(3) 1973, pp : 66-9..

176. Tomar, N.S. Fruiting potential and quality of 'Perlette' grape 'Vitis Vinifera' with differential pruning trained on head system. Indian J. of Agril. Sc. 60(5) 1990. pp: 327-31.

177. Visvanathan, R; N.Varadharaju; L.Gothandapani and V.V. Sreenarayanan. Effect of moisture content on angle of repose and bulk density of selected grains. J.F. Sci. Technol. Vol. 27(3) 1990; pp.133-5.

178. Wolfe, R.R. and C.G. Ttepo. Terminal velocity of chopped forage materials. Trans. ASAE. 1972. pp: 137-40.

APPENDIX-I

Glossary of food products with botanical and hindi names

Product	Botanical name	Hindi name	
CEREAL GRAINS AND PRODUCTS			
Bara (bulrush spiked millet)	*Pennisetum typhoides*	Bajra	बाजरा
Barley	*Hordeum vulgare*	Jau	जौ
Barnyard millet	*Echinochloa frumemtacea*	Kutki	कुटकी
Common millet	*Panicum millaceum*	Cheena	चीना
Jowar (sorghum)	*Sorghum vulgare*	Juar	ज्वार
Kodo millet	*Paspalum Scrobiculatum*	Koden	कोदों
Maize (corn)	*Zea mays*	Maka	मक्का
Pearl millet (bajra)	*Pennisetum typhoideum*	Bajra	बाजरा
Ragi	*Eleusine coracana*	Madua	मदुआ
Rice (parboiled)	*Oryza sativa*	Usna chawal	उसना चावल
Rice (raw)	*Oryza sativa*	Chawal	चावल
Rice (bran)	*Oryza sativa*	Kanki	कनकी
Rice (flakes)	*Oryza sativa*	Chewra	चेवड़ा
Rice (puffed)	*Oryza sativa*	Murmura	मुरमुरा
Sanwa millet	*Echinochloa frumantacea*	Sanwa	सावां
Semolina	*Triticum aestivum*	Sooji	सूजी
Wheat	*Triticum aestivum*	Gehun	गेहूँ
Wheat flour (whole)	*Triticum aestivum*	Atta	आटा
Wheat flour (fine)	Triticum aestivum	Maida	मैदा
PULSES			
Bengal gram (whole)	*Cicer arietinum*	Chana	चना
Bengal gram (dhal)	*Cicer arietinum*	Chane ki dal	चने की दाल
Bengal gram (chick pea) flour	*Cicer arietinum*	Besan	बेसन
Bengal gram (roasted)	*Cicer arietinum*	Bhuna chana	भुना चना
Black gram (dhal)	*Phaseolus mungo Roxb*	Urd dal	उर्ददाल
Cow pea	*Vigna catjang*	Lobia	लोबिया
Faba Bean	*Vicia faba L.*	–	–
Field bean	*Dolichos lablab*	Kadumal	कदूमाल
Green gram (whole)	*Phaseolus aureus Roxb*	Mung	मूँग

Product	Botanical name	Hindi name	
Green gram (dhal)	*Phaseolus aureus Roxb*	Mung dal	मूंग दाल
Horse gram	*Dolichos biflorus*	Kulthi	कुलथी
Khesari dhal	*Lathyrus sativus*	Khesari dal	खेसरी दाल
Lentil	*Lens esculenta*	Masur	मसूर
Lima beans	*Phaseolus lunatus L.*	Lima sem	लाइमा सेम
Moth beans	*Phaseolus aconitifolieus, Jacq.*	Moth	मोठ
Peas	*Pisum sativum*	Matar	मटर
Rajmah	*Phaseolus vulgaris*	Rajmah	राजमा
Red gram (dhal) (pigeon pea)	*Cajanus cajan*	Arhar dal	अरहर दाल
Soy bean	*Glycine max Merr*	Soyabean	सोयाबीन
Winged beans	*Psophocarpus teraganolobus (L) DC*	–	–

LEAFY VEGETABLES

Agathi	*Sesbania grandiflora*	Agasti	अगस्ती
Amaranth (spined)	*Amaranthus spinosus*	Kantewali chaulai	कांटे वाली चौलाई
Amaranth (tender)	*Amaranthus gangeticus*	Chaulai sag	चौलाईसाग
Bamboo (tender shoots)	*Bambusa arundinacea*	Bans	बांस
Bathua leaves	*Chenopodium album*	Bathua sag	बथुवासाग
Beet greens	*Beta vulagaris*	Chukandar-ka-sag	चुकन्दर का साग
Bengal gram leaves	*Cicer arietinum*	Chana sag	चना साग
Bottle gourd leaves	*Lagenaria vulgaris*	Lauki-ka-sag	लौकी का साग
Broad been leaves	*Vicia faba*	Bakala	बाकला
Brussels sprouts	*Brassica oleracea var. gemmifera*	Chotee gobee	छोटी गोभी
Cabbage	*Brassica oleracea var. capitata*	Band gobee	बंद गोभी
Carrot leaves	*Daucus carota*	Gajar sag	गाजर साग
Cauliflower greens	*Brassica oleracea var. botrytis*	Phool gobee sag	फूल गोभी साग
Celery leaves	*Apium graveolens var. dulce*	Ajwan-ka-patta	अजवाइन का पत्ता
Colocasia leaves	*Colocasia antiquorum*	Arivi-ka-sag	अरबी का साग
Coriander leaves	*Coriandrum sativum*	Haradhania	हराधनिया
Cowpea leaves	*Vigna catjang*	Chavli pan	चावली पान
Curry leaves	*Murraya koenigii*	Gandhela	गंधेला
Drumstick leaves	*Moringa oleifera*	Sajan patta	साजन पत्ता
Fenugreek leaves	*Trigonella foenumgraecum*	Methi sag	मेथी साग
Khesari leaves	*Lathyrus sativus*	Khesari sag	खेसरी साग
Knol-khol greens	*Brassica oleracea var. caulorapa*	Ganth gobi- ka-sag	गांठ गोभी का साग
Lettuce	*Lactuca sativa*	Salad	सलाद
Mint	*Mentha spicata*	Pudina	पुदिना
Mustard leaves	*Brassica campestris var. sarason*	Sarson-ka-sag	सरसों का साग
Neem leaves	*Azadirachta indica*	Neem-ke-patte	नीम के पत्ते
Nerringi	*Tribulus terrestris*	Gokhru	गोखरु
Pacharisí keerai	*Euphorbia hirta*	Dudhi	दूधी

Product	Botanical name	Hindi name	
Paruppu keerai	*Portulaca oleracea*	Kulfa	कुल्फा
Parwar sag	*Trichosanthes dioica*	Potol sag	पटोल साग
Pumpkin leaves	*Cucurbita maxima*	Kumhra sag	कुमढ़ा साग
Radish leaves	*Raphanus sativus*	Moli-ka-sag	मूली का साग
Rape leaves	*Brassica napus*	Sag sarson	सरसों का साग
Shepu	*Peucedanum graveolens*	Sowa	सोआ
Spinach	*Spinacia oleracea*	Palak	पालक
Sweet potato greens	*Ipomoea batatas*	Shakarkand sag	शकरकंद साग
Turnip greens	*Brassica rapa*	Shalgam-ka-sag	सलजम का साग

ROOTS AND TUBERS

Beet root	*Beta vulgaris*	Chukandar	चुकंदर
Bokwa	*Dioscorea pentaphylla*	Kanta alu	कांताआलू
Carrot	*Daucus carota*	Gajar	गाजर
Colocasia	*Colocasia antiquorum*	Arwi	अरबी
Lotus root	*Nelumbium nelumbo*	Kamal-ki-jadh	कमल की जड़
Onion	*Allium cepa*	Pyaz	प्याज
Potato	*Solanum tuberosum*	Alu	आलू
Radish	*Raphanus sativus*	Muli	मूली
Sweet potato	*Ipomoea batatas*	Shakarkand	शकरकंद
Tapioca (cassava)	*Maninot esculenta*	Simla alu	शिमला आलू
Turnip	*Brassica rapa*	Shalgam	सलजम
Yam, elephant	*Amorphophallus campanulatus*	Zimikand	जिमीकंद
Yam, wild	*Dioscorea versicolor*	Suar alu	सोर आलू

OTHER VEGETABLES

Amaranth stem	*Amaranthus gangeticus*	Cholai-ki-dandi	चौलाई की दंडी
Ash gourd	*Benincasa hispida*	Petha	पेठा
Beans, scarlet runner	*Phaseolus coccineus*	Sem	सेम
Bitter gourd	*Momordica charantia*	Karela	करेला
Bottle gourd	*Lagenaria vulgaris*	Lowki	लौकी
Brinjal (egg plant)	*Solanum melongena*	Baingan	बैंगन
Broad beans	*Vicia faba*	Bakla	बाकला
Cauliflower	*Brassica oleracea var. botrytis*	Phul gobi	फूलगोभी
Cluster beans	*Cyamopsis tetragonoloba*	Guar ki phalli	ग्वार की फली
Colocasia stem	*Colocasia antiquorum*	Arwi-ki-dandi	अरबी की दंडी
Cucumber	*Cucumis sativus*	Khira	खीरा
Drumstick	*Moringa oleifera*	Sajan-ki-phalli	साजन की फली
Figs	*Ficus cunia*	Anjeer	अंजीर
French beans	*Phaseolus vulgaris*	Bakla	बाकला

Product	Botanical name	Hindi name	
Giant chillies (capsicum)	*Capsicum annum var. grossa*	Sagiya mirchi	सांगिया मिर्चा
Jack, tender	*Artocarpus heterophyllus*	Kathal	कटहल
Kankoda	*Momordica dioica*	Golkand	गोलकंद
Karonda	*Carissa carandas*	Karonda	करौंदा
Kovai	*Coccinia cordifolia*	Konduru	कुंदरु
Knol-khol	*Brassica oleracea*	Kohl-rabi (Ganth gobi)	गांठगोभी
Ladies fingers (okra)	*Abelmoschus esculentus*	Bhindi	भिंडी
Leeks	*Allium porrum*	Lasson (vilayiti)	लासन
Lotus stem	*Nelumbium nelumbo*	Kamal gatta	कमलगट्टा
Mango green	*Mangifera indica*	Aam	आम
Onion stalks	*Allium cepa*	Pyaz	प्याज
Papaya, green	*Carica papaya*	Papita	पपीता
Parwar	*Trichosanthes dioica*	Parwal	परवल
Peas	*Pisum sativum*	Matar	मटर
Plantain flower	*Musa sapientum*	Kele-ka-phool	केले का फूल
Plantain, green	*Musa sapientum*	Kela(hara)	केला (हरा)
Plantain stem	*Musa sapientum*	Kele-ka-tana	केले का तना
Pumpkin	*Cucurbita maxima*	Kaddu	कद्दू
Pumpkin flowers	*Cucurbita maxima*	Kaddu-ka-phool	कद्दू का फूल
Rape plant stem	*Brassica napus*	Sarson-ki-dandi	सरसों की दंडी
Ridge gourd	*Luffa acutangula*	Torai	तोराई
Sannhemp flowers	*Crotalaria juncea*	Sanai-ka-phool	सनई का फूल
Silk-cotton flowers	*Bombax malabaricum*	Semal-ka-phool	सेमल का फूल
Snake gourd	*Trichosanthes anguina*	Chachinda	चचींडा
Sword beans	*Canavalia gladiata*	Bara sem	बड़ा सेम
Tinda	*Citrullus vulgaris*	Tinda	टिण्डा
Tomato green	*Lycopersicon esculentum*	Tamator	टमाटर
Vegetable marrow	*Cucurbita pepo*	Safed kaddu	सफेद कद्दू
Water chestnut	*Trapa bispinosa*	Shingara	सिंगाड़ा
Water lily flowers	*Nymphaea nouchali*	Bhent-ka-phool	भेंत का फूल

NUTS AND OILSEEDS

Almond	*Prunus amygdalus*	Badam	बादाम
Cashew nut	*Anacardium occidentale*	Kaju	काजू
Castor seed	*Ricinus communis*	Rendi	रेंडी
Chilgoza	*Pinus gerardiana*	Chilgoza	चिलगोजा
Coconut	*Cocos nucifera*	Nariyal	नारियल
Coffee seed	*Coffee arabica*	Coffee	कॉफी
Cotton seed	*Gossypium species*	Binola	बिनौला
Gingelly seeds	*Sesamum indicum*	Til	तिल
Groundnut	*Arachis hypogaea*	Moong phali	मूंगफली

Product	Botanical name	Hindi name	
Linseed seeds	*Linum usitatissimum*	Alsi	अलसी
Mustard seeds	*Brassica nigra*	Rai	राई
Niger seeds	*Guizotia abyssinica*	Sham til	शम तिल
Pistachio nut	*Pistacia vera*	Pista	पिस्ता
Pongam	*Pongamia glabra*	Karanj	करंज
Rape seeds	*B. campestris*	Sarson	सरसों
Safflower seeds	*Carthamus tinctorius*	Kardi, Kusam	करडी, कुसुम
Sesamum seeds	*Sesamum indicum*	Til	तिल
Soybean	Glycine max merr	Soyabean	सोयाबीन
Sunflower seeds	*Helianthus annuus*	Suraj mukhi	सूरजमुखी
Tea	*Camellia thea*	Chay	चाय
Walnut	*Juglans regia*	Akhrot	अखरोट

CONDIMENTS AND SPICES

Aniseed	*Pimpinella anisum L.*	Somph	सौंफ
Arisithippili	*Peepal*	Peeper	पीपर
Asafoetida	*Ferula foetida*	Hing	हींग
Bishopsweed	*Corum captimum*	Ajwain	अजवाइन
Caraway	–	Amaltaas	अमलतास
Cardamom	*Elettaria cardamomum*	Elaychi	इलायची
Celery	–	Celery	सेलरी
Chillies	*Capsicum annuum*	Mirch	मिर्च
Cinnamon	–	Dalchini	दालचीनी
Cloves	*Syzygium aromaticum*	Lavang	लौंग
Coriander	*Coriandrum sativum*	Dhania	धनिया
Cumin seeds	*Cuminum cyminum*	Safed jira	सफेद जीरा
Curry leaf	–	Kady pati	कड़ी पत्ती
Dill	*Anethum gravcolens*	Soaa	सोआ
Fennel	–	Kallonji	कलौंजी
Fenugreek seeds	*Trigonella foenum graecum*	Methi	मेथी
Garlic	*Allium sativum*	Lehsan	लहसुन
Ginger, fresh	*Zinziber officinale*	Adrak	अदरक
Kokam	–	Kukum	कुकुम
Lime peel	*Citrus medica var. acida*	Neebu-ka-chilka	नींबू का छिलका
Mace	*Myristica fragrans*	Javithri	जावित्री
Mint	–	Pudhena	पुदीना
Nutmeg	*Myristica fragrans*	Jaiphal	जायफल
Omum	*Trachyspermum ammi*	Ajwan	अजवायन
Parseley	–	Ajmodh	अजमोध
Pepper	*Piper nigrum*	Kalimirch	काली मिर्च
Saffron	–	Kesar	केसर
Tamarind pulp	*Tamarindus indica*	Imli	इमली

Product	Botanical name	Hindi name	
Thyme	–	Thime (banjvayan)	थीइम (बनजवायन)
Tejpat	–	Tejpatta	तेजपत्ता
Turmeric	*Curcuma domestica*	Haldi	हल्दी
Vanilla	–	Vanilla	वनीला

FRUITS

Indian gooseberry (amla)	*Emblica officinalis*	Amla	आंवला
Apple	*Malus sylvestris*	Sev	सेव
Apricot	*Prunus armeniaca*	Khoobani	खुबानी
Avacado pear	*Persea americana*	–	–
Bael fruit	*Aegle marmelos*	Bel	बेल
Banana, ripe	*Musa paradisiaca*	Kela	केला
Banyan tree figs	*Ficus bengalensis*	Bargad-ka-phal	बरगद का फल
Blackberry	*Rubus fruiticosus*	Vilaiti-anchu	विलायती अन्छू
Bread fruit	*Artocarpus altilis*	Madar	मदार
Cape gooseberry	*Physalis peruviana*	Rasberi	रसबेरी
Cashew fruit	*Anacardium occidentale*	Kajuphal	काजूफल
Cherries, red	*Prunus cerasus*	Gilas	गिलास
Cherimoyer	*Annona cherimolia*	Hanuman phal	हनुमान फल
Currants, black	–	Munakka	मुनक्का
Dates	*Phoenix dactylifera*	Khajur	खजूर
Figs	*Ficus carica*	Anjeer	अंजीर
Grape	*Vitis vinifera*	Angoor	अंगूर
Grapefruit	*Citrus paradisi*	Chakotra	चकोतरा
Guava, country	*Psidium guajava*	Amrud	अमरुद
Jack fruit	*Artocarpus heterophyllus*	Kathal	कटहल
Jambu fruit	*Syzygium cumini*	Jamun	जामुन
Kila pazham	*Vaccinum leschenaultii*	Karaunda	करौंदा
Kusum fruits	*Achleichera trijuga*	Kusum-ka-phal	कुसुम का फल
Lemon	*Citruslimom*	Bara nimbu	बड़ा नींबू
Lemon, sweet	*Citrus limetta*	Mitha nimbu	मीठा नींबू
Lichi	*Nephelium litchi*	Lichi	लीची
Lichi, bastard	*Nephelium longana*	Ansphal	अंशफल
Lime	*Citrus aurantifolia*	Neembu	नींबू
Lime, sweet (musammi)	*Citrus sinensis*	Musambi	मुसम्बी
Loquat	*Eriobotrya japonica*	Lokat	लोकट
Mahua, ripe	*Bassia longifolia*	Mahua	महुआ
Mango, ripe	*Mangifera indica*	Aam (paka)	पक्का आम
Melon, musk	*Cucumis melo*	Kharbooja	खरबूजा
Melon, water	*Citrulls vulgaris*	Tarbuj	तरबूज
Mulberry,	*Morus sp.*	Shahtoot	शहतूत
Neem fruit	*Malia azadirachta*	Neem phal	नीमफल

Product	Botanical name	Hindi name	
Orange	*Citrus aurantium*	Narangi	नारंगी
Papaya, ripe	*Carica papaya*	Papita	पपीता
Passion fruit	*Passiflora edulis*	–	
Peaches	*Amygdalis persica*	Aarhoo	औरहू
Pears	*Prunus persica*	Nashpati	नाशपात्ती
Phalsa	*Grewia asiatica*	Falsa	फालसा
Pine apple	*Ananas comosus*	Ananas	अनानास
Plum	*Prunus domestica*	Alubokhara	आलू बुखारा
Pomegranate	*Punica granatum*	Anar	अनार
Pummelo	*Citrus maxima*	Chakotra	चकोतरा
Quince	*Cydonia oblonga*	Bihi	बीही
Raisins	*Vitis vinifera*	Kishmish	किशमिश
Raspberry	–	Rusbhary	रुसबेरी
Sapota	*Achras sapota*	Sapatu	सपातू
Seethaphal	*Annona squamosa*	Sharifa	सरीफा
Squash melon	–	Squash melon	स्क्वेश मेलन
Strawberry	*Fragaria vesca*	Strawberry	स्ट्राबेरी
Summer melon	*Cucumis melo L.*	–	–
Water melon	*Citrullus vulgaris sohrad*	Tarbooj	तरबूज
Wood apple	*Limonia acidissima*	Kaitha	कैथा
Zizyphus	*Zizyphus jujuba*	Ber	बेर

MISCELLANEOUS FOODS

Amaranth seeds	*Amaranthus sp.*	Jangli chowlai	जंगली चौलाई
Areca nut	*Areca catechu*	Supari	सुपारी
Betel leaves	*Piper betle*	Pan-ka-pata	पान का पत्ता
Cane sugar	*Saccharum officinarum*	Ghanna	गन्ना
Coconut milk	*Cocos nucifera*	Nariyal-ka-doodh	नारियल का दूध
Coconut water	*Cocos nucifera*	Nariyal-ka-pani	नारियल का पानी
Groundnut cake	*Arachis hypogaea*	Chinia badam-ki-khali	चीनिया बादाम की खली
Honey	–	Shaihad	शहद
Jaggery	–	Gud	गुड़
Makhana (gorgon nut)	*Eurvale ferox*	Makhana	मखाना
Mango seed kernel	*Mangifera indica*	Am-ki-guthli	आम की गुठली
Mango powder	*Mangifera indica*	Amchoor	अमचुर
Marking nut	*Semecarpus anacardium*	Velwa-ka-topi	वेलवा का टोपी
Mushroom	–	Khummi	खुम्मी
Poppy seeds	*Papaver somniferum*	Post dana	पोस्त दाना
Sago	–	Sabu dana	साबू दाना
Sugar cane juice	–	Ganne-ka-ras	गन्ने का रस

APPENDIX - II

Standard curves for various properties of food crops

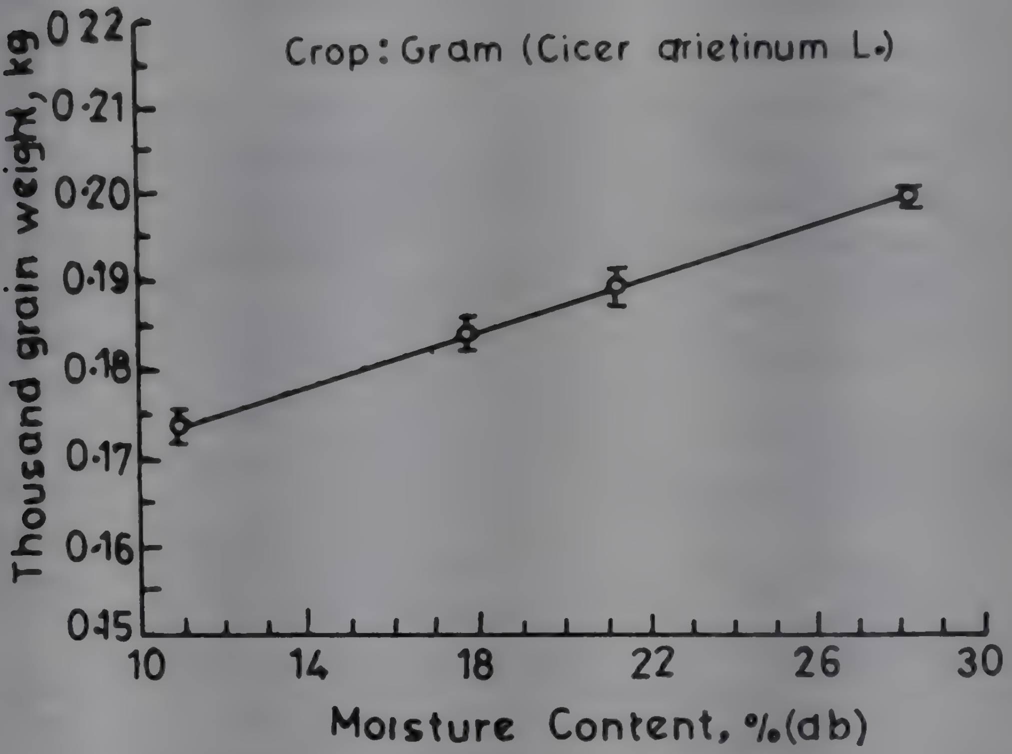


Fig. A1 : Variation of thousand grain weight with moisutre content

Source : Dutta, S.K; V.K. Nema and R.K. Bhardwaj. Physical properties of gram. Jr. of Agril. Engng. Res. 1988, 39 (4). pp: 259-68.

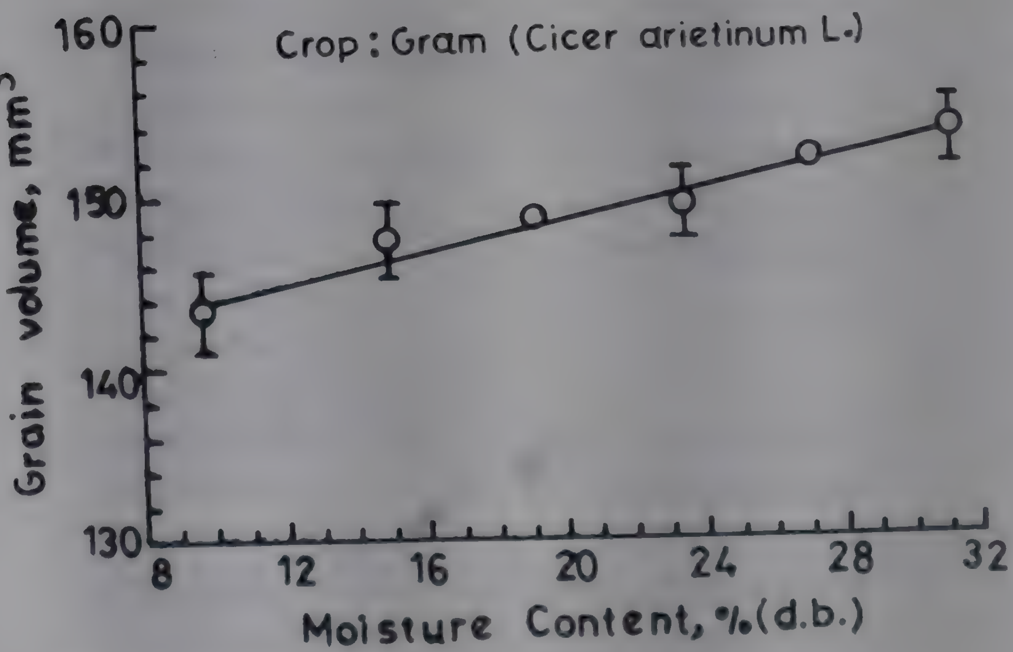


Fig. A2 : Variation of grain volume with moisture content

Source : Dutta, S.K; V.K. Nema and R.K. Bhardwaj. Physical properties of gram. Jr. of Agril. Engng. Res. 1988, 39 (4). pp: 259-68.

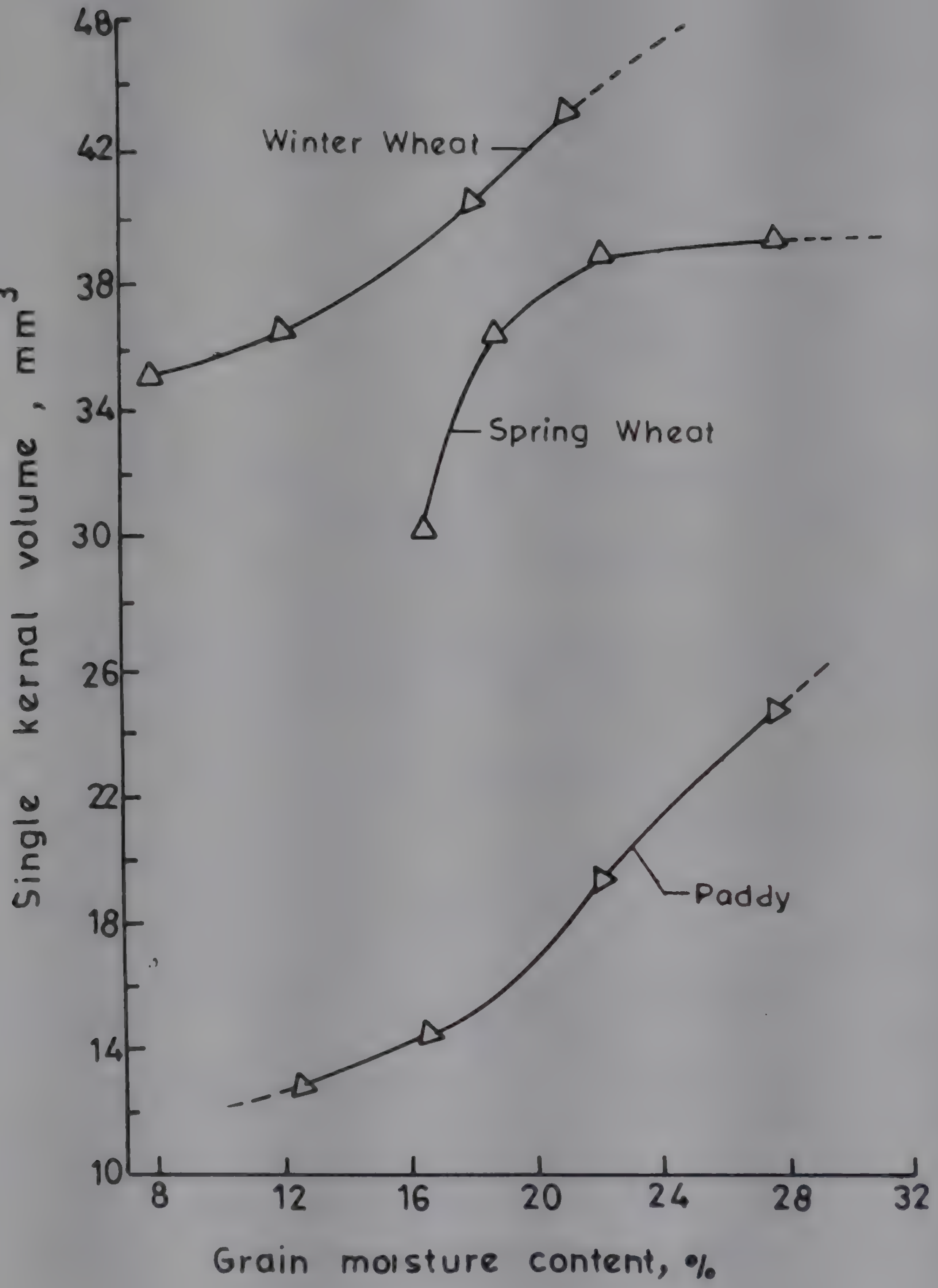


Fig. A3 : Single kernal volume v/s grain moisture content

Source : Islam Md. Nural and T.T. Pedresen. Some physical properties of wheat and paddy and their relationship. AMA, 1987, 18 (1). pp : 45-50.

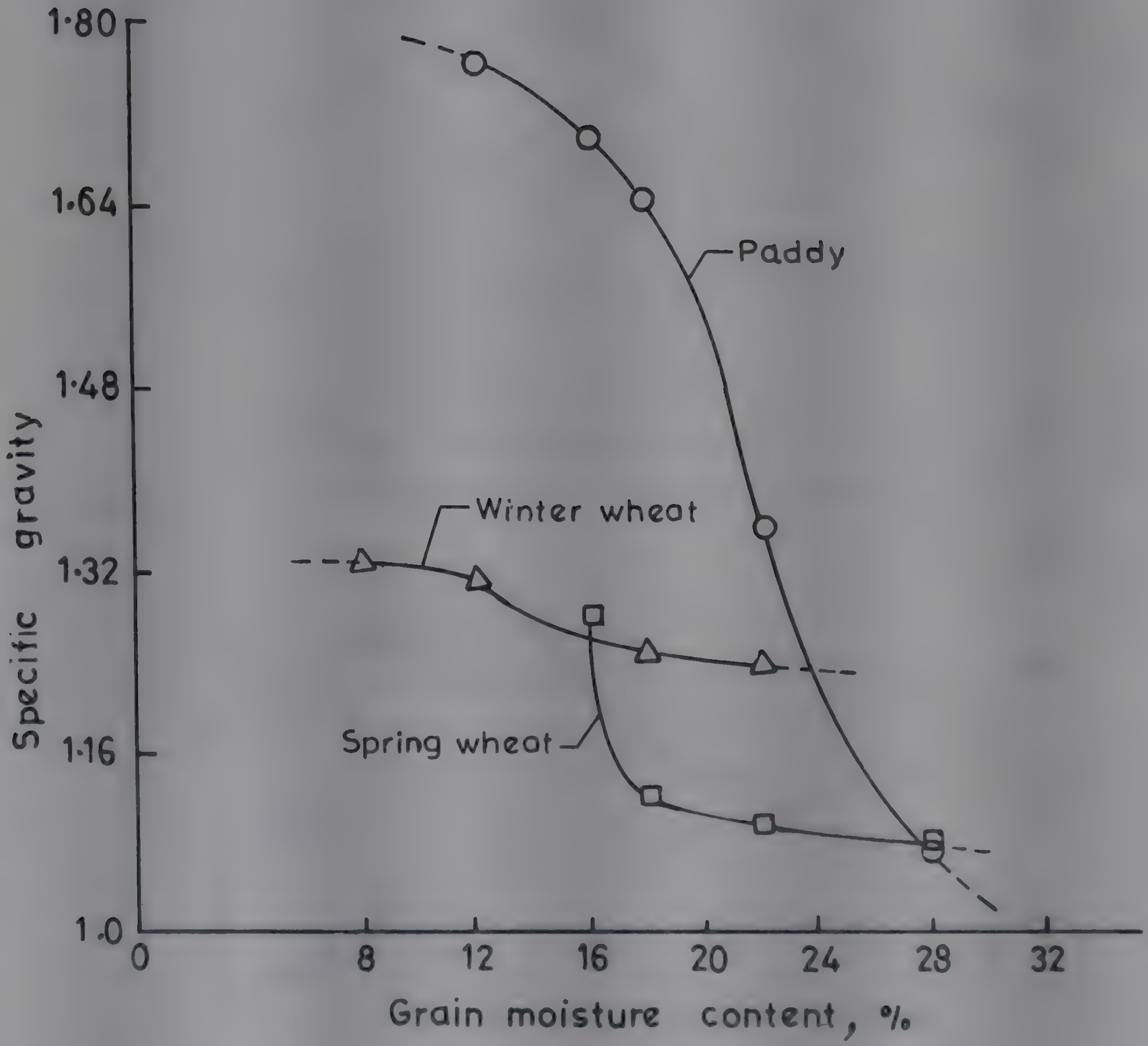


Fig. A 4 : Specific gravity v/s moisture content of grain

Source : Islam Md. Nural and T.T. Pedresen. Some physical properties of wheat and paddy and their relationship. AMA, 1987, 18(1). pp: 45-50.

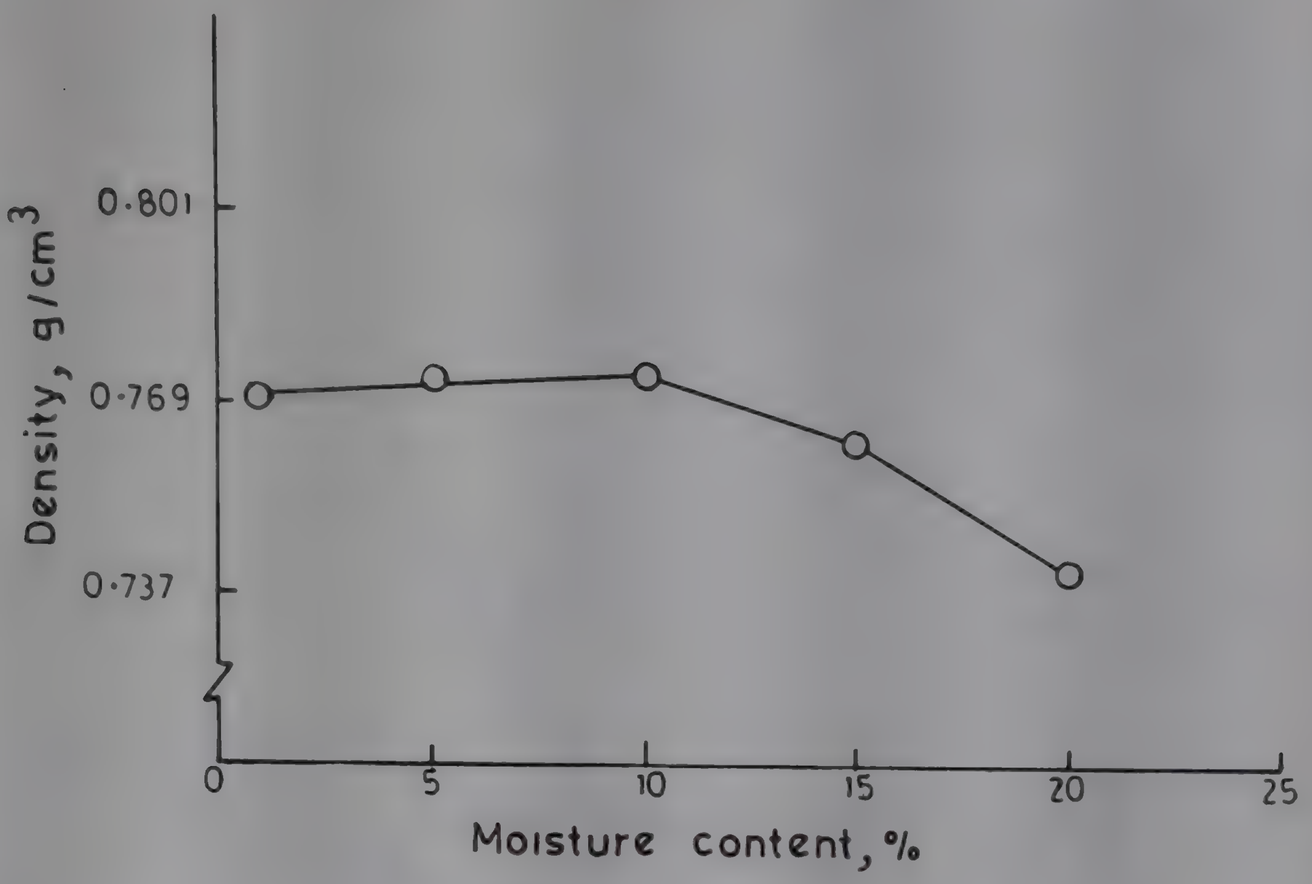


Fig. A5 : Relation between density and moisture content for soft white wheat

Source : Kazarian, E.A. and C.W. Hall. Thermal properties of grains. Trans. ASAE. 1965, 8(1). pp : 337-48.

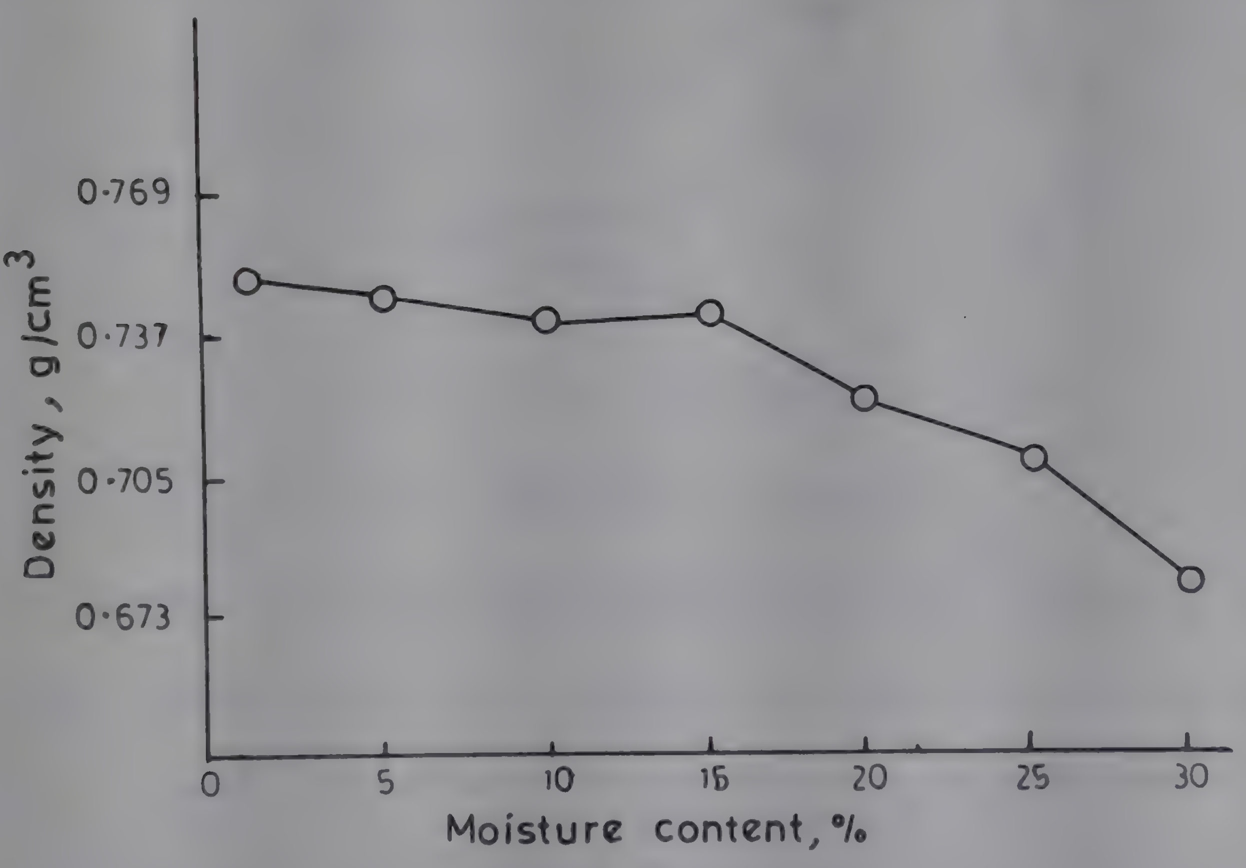


Fig. A6 : Relation between density and moisture content for corn

Source : Kazarian, E.A. and C.W. Hall. Thermal properties of grains. Trans. ASAE. 1965, 8(1). pp : 337-48.

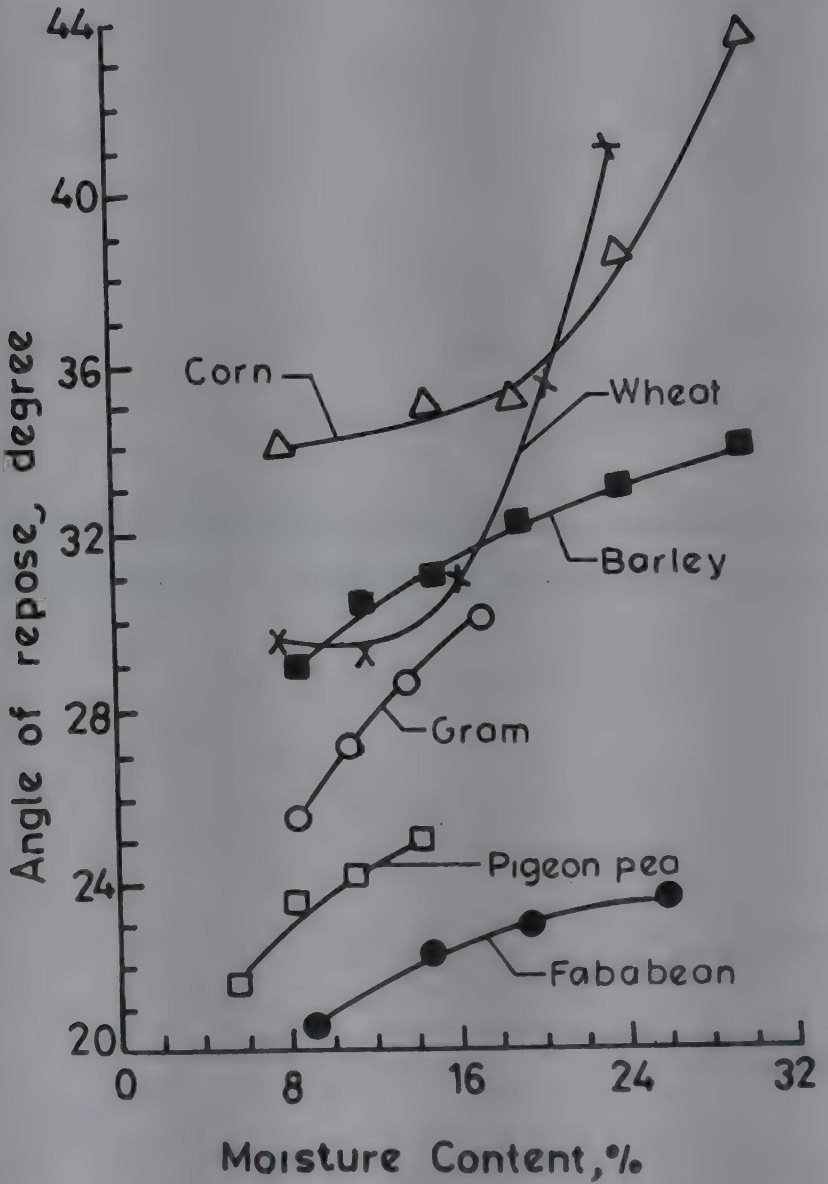


Fig. A7 : Change of angle of repose for different grains with moisture content

Source :

1. Datta, S.K.; V.K. Nema and R.K. Bhardwaj. Physical properties of grain. J. Agril. Engng. Res. 1988, 39 (4). pp : 259-68.
2. Fraser, B.M.; S.S.Verma and W.E. Muir. Some physical properties of fababeans. J. Agril. Engng. Res. 1987, 23. pp : 53-7.
3. Lorenzen, C. Moisture effect on granular friction of small grains. Trans. ASAE. 1959. Paper No. 59-416.
4. Shepherd, H; R.K. Bhardwaj. Moisture dependent physical properties of pigeon pea. J. Agril. Engng. Res. 1986, 35. pp: 227- 34.

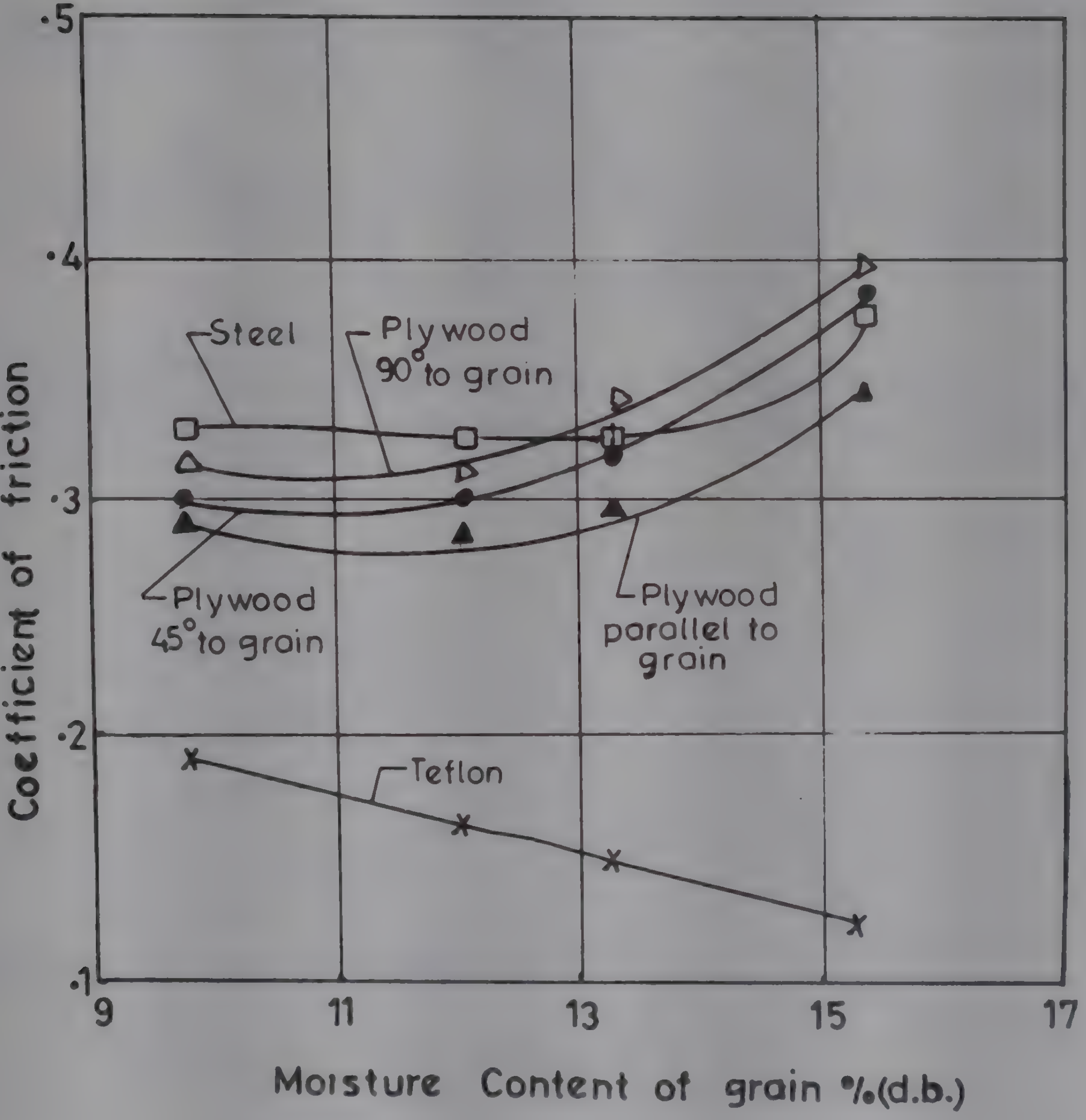


Fig. A8 : Static coefficient of friction of wheat on five surfaces

Source : Brubaker, J.E. and J.Pos. Determining static coefficient of friction of grains on structural surfaces. Trans. ASAE. 1965, 8 (1), pp : 53-5.

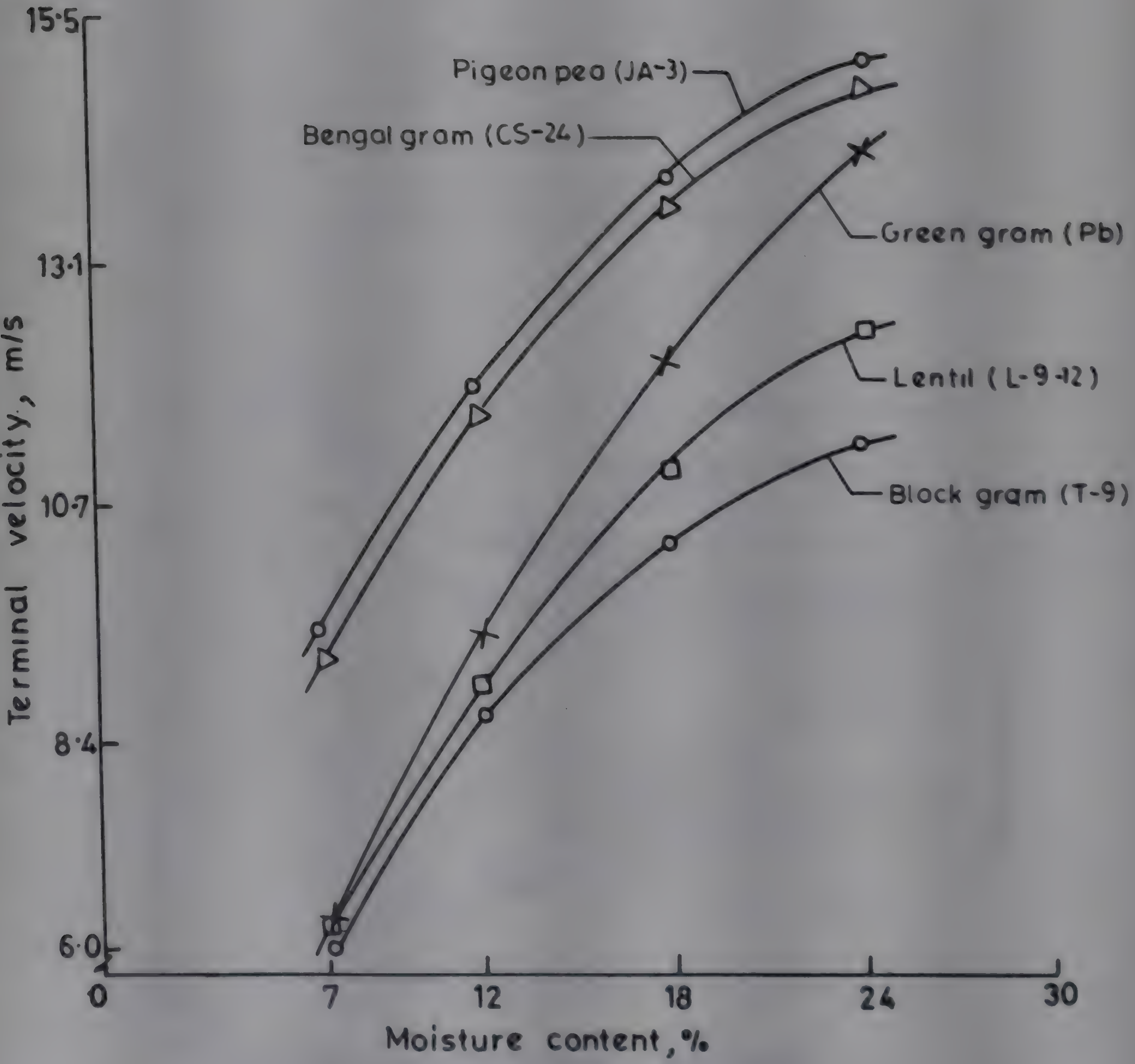


Fig. A9 : Effect of moisture content on terminal velocity of grains

Source : Gupta, R.K. and Saurabh Prakash. Final Report (RPF- III). Studies on physical, aerodynamic, rheological, thermal and biological properties of oilseeds and pulses. 1991. CIAE. Bhopal.

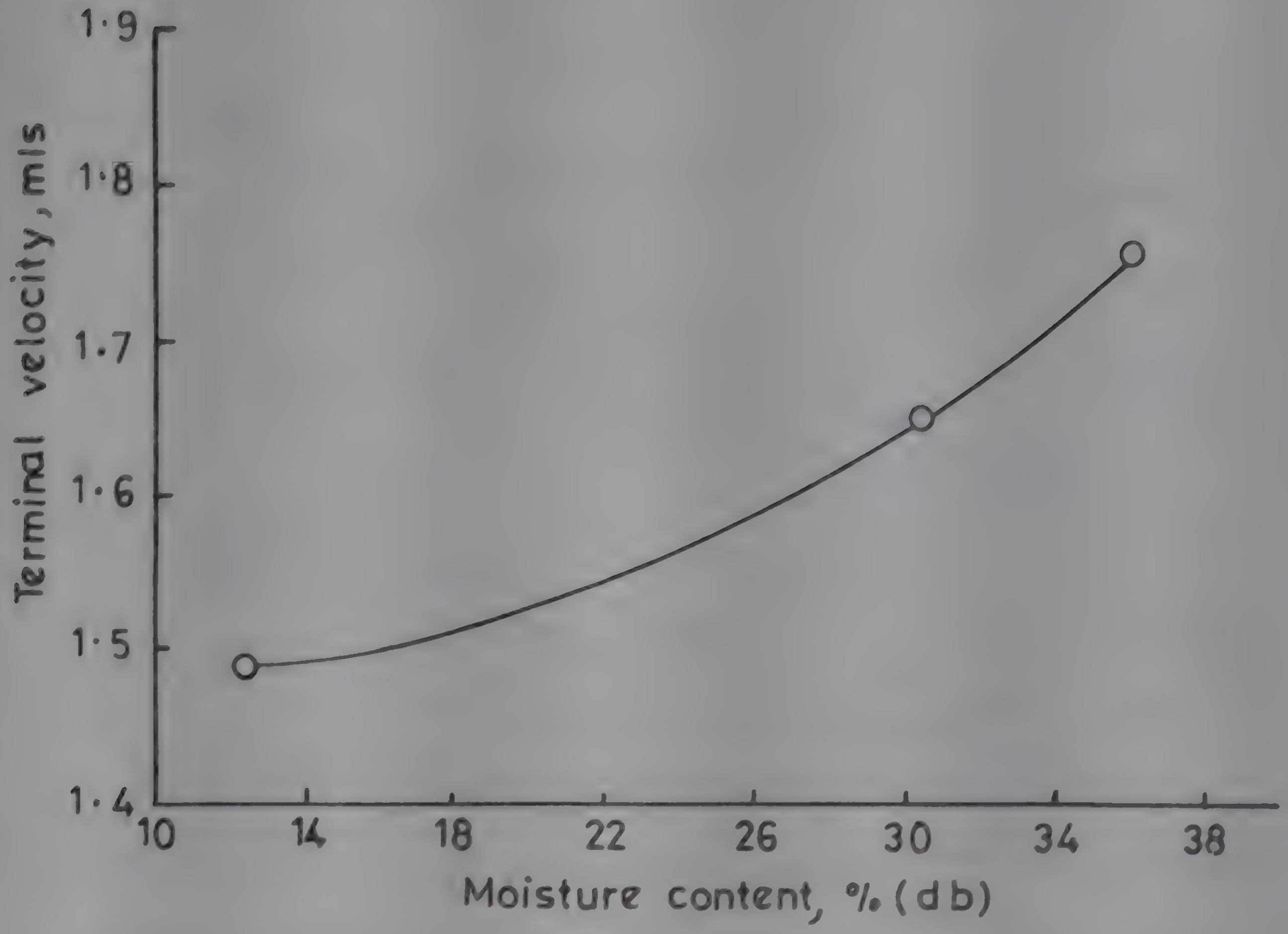


Fig. A10 : Terminal velocity of rice husk as a function of its moisture content

Source : Singh, Harpal. A study of pressure drop in pneumatic conveying of rice husk. Unpublished Dissertation, 1990. AIT, Bangkok, Thailand, pp : 59.

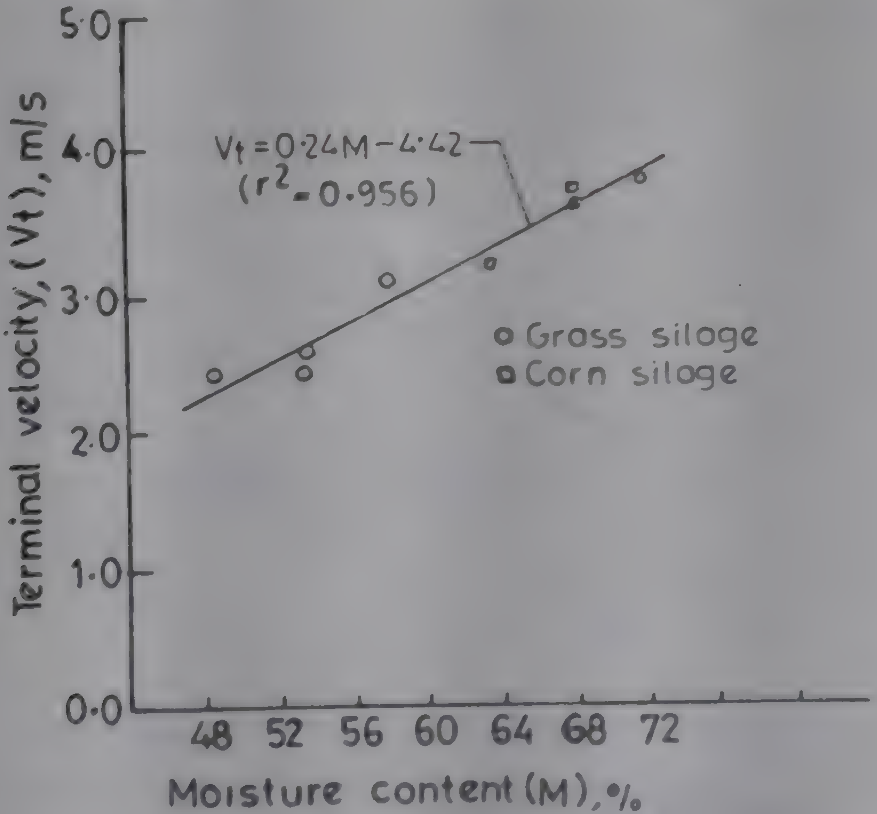


Fig. A11 : Effect of moisture content on the terminal velocity of chopped forage

Source : Wolfe, R.R. and C.G. Tatepo. Terminal velocity of chopped forage materials. Trans. ASAE. 1972, pp 137-40.

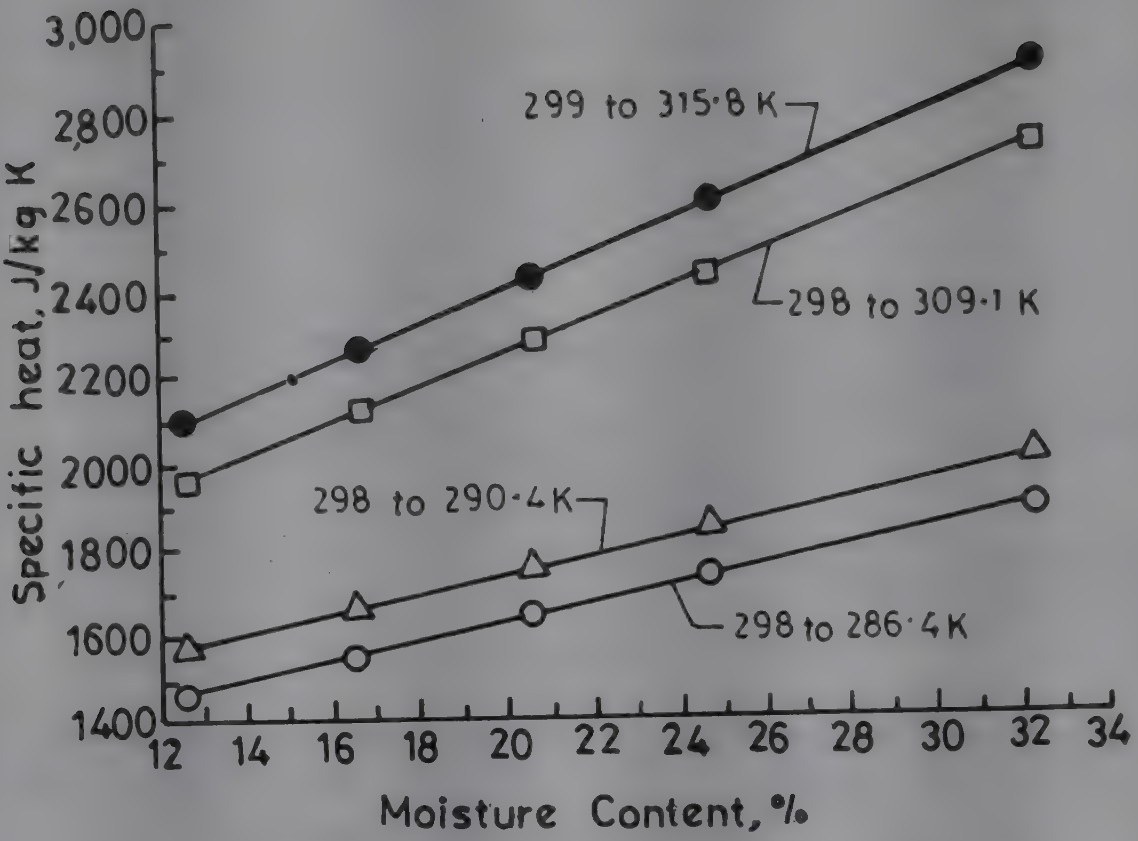


Fig. A12 : Variation of specific heat of gram with moisture content in different temp. ranges

Source : Dutta, S.K.; V.K. Nema, and R.K. Bhardwaj. Thermal properties of gram. Jr. of Agril. Engg. Res. 1988, 39 (4), pp: 269-75.

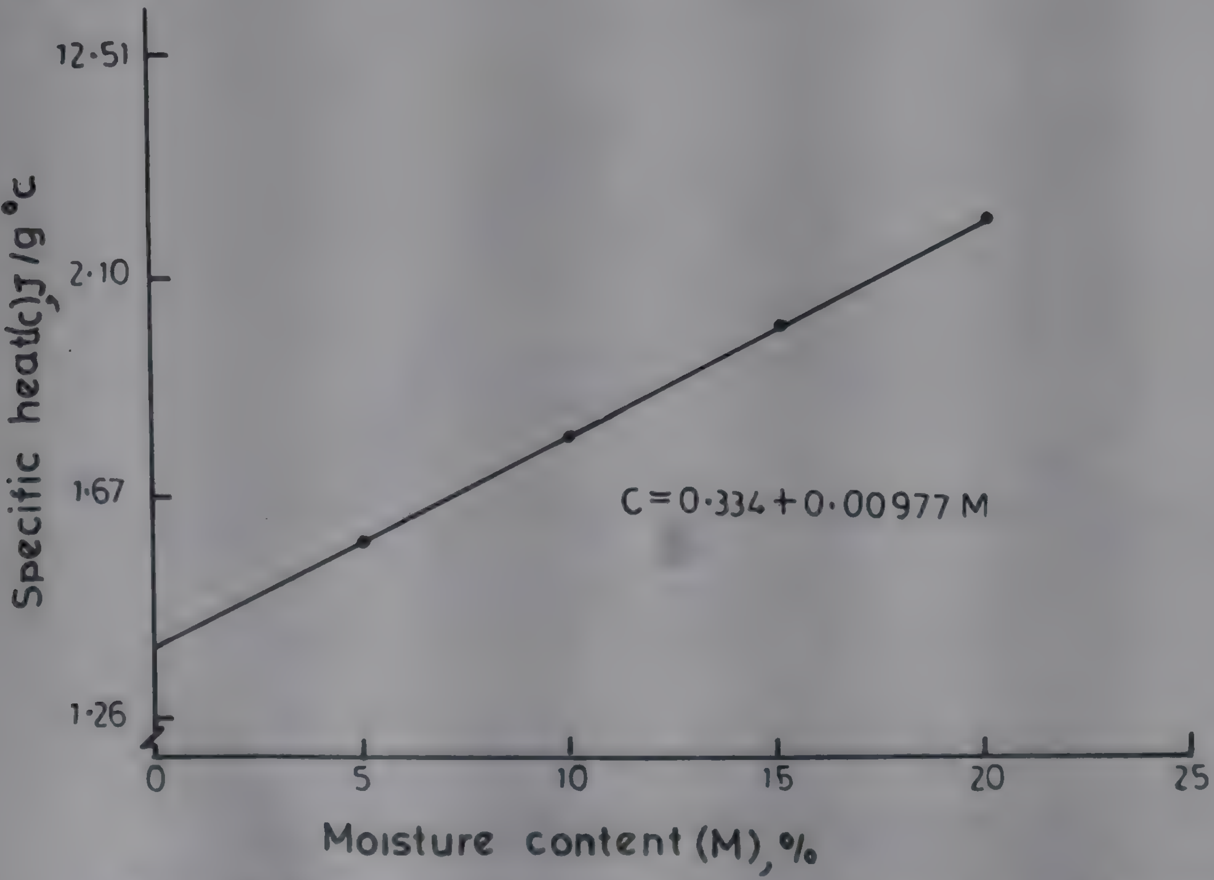


Fig. A13 : Relation between specific heat and moisture content for wheat

Source : Kazarian, E.A. and C.W. Hall. Thermal properties of grains. Trans. ASAE. 1965, 8 (1). pp : 337-48.

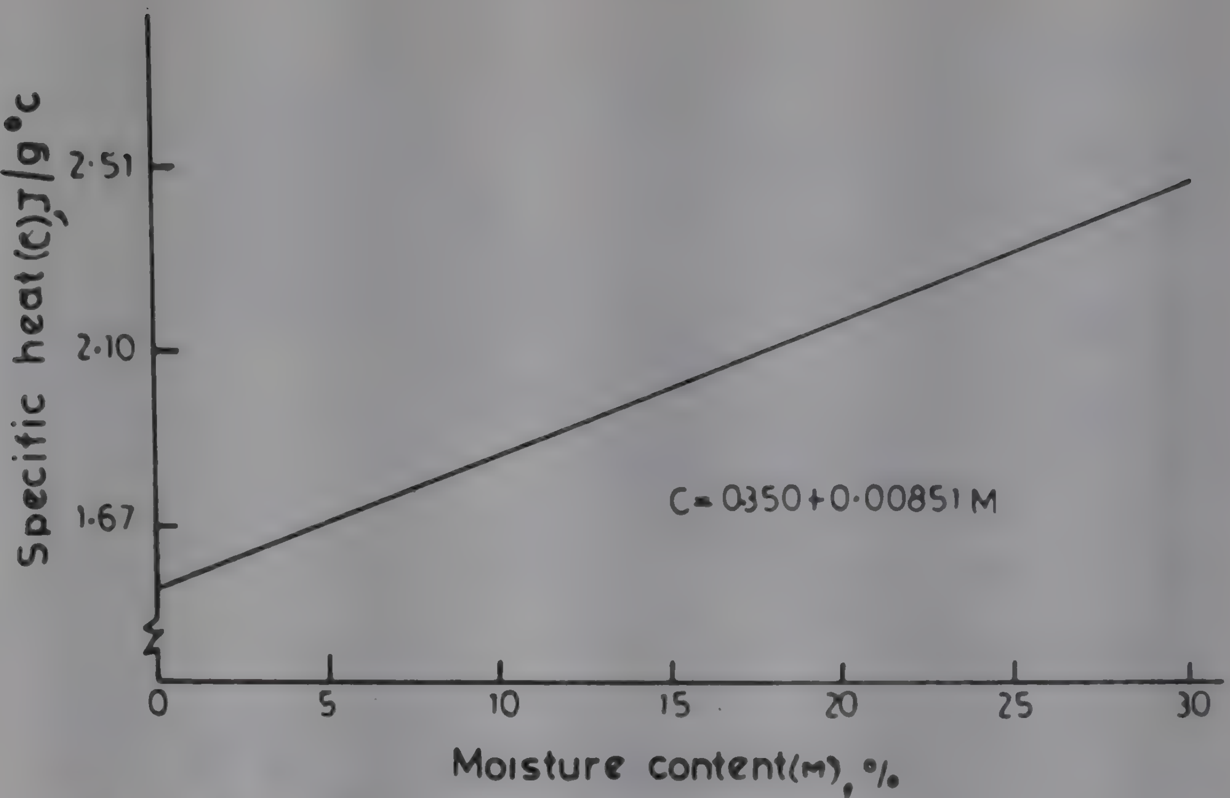


Fig. A14 : Relation between specific heat and moisture content for corn

Source : Kazarian, E.A. and C. W. Hall. Thermal properties of grains. Trans. ASAE. 1965, 8 (1), pp : 337-48.

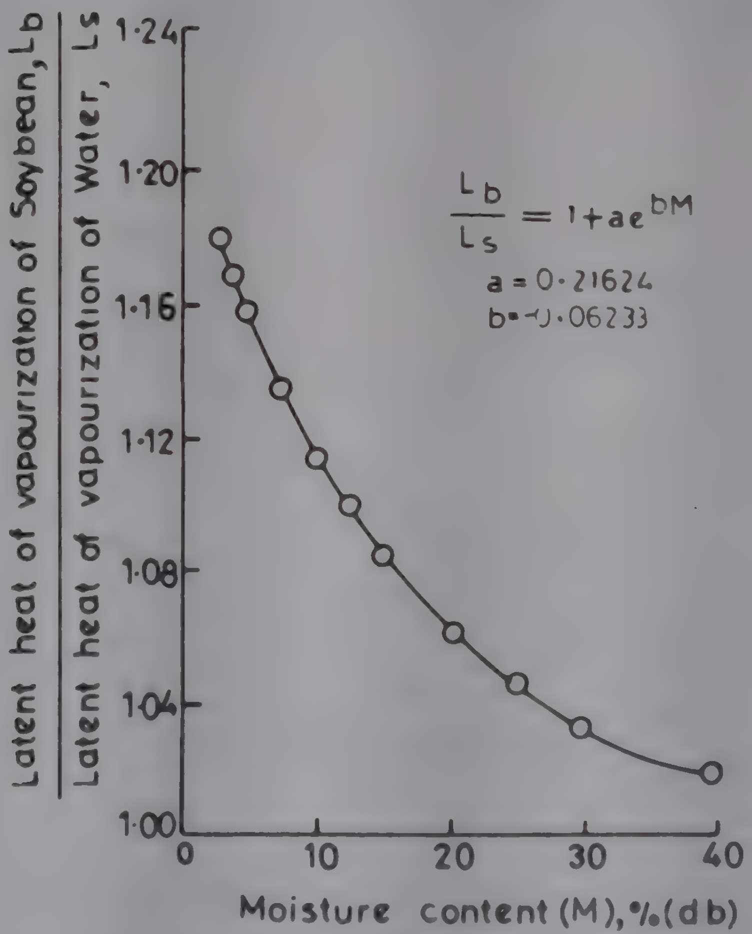


Fig. A15 : Predicted variation of the ratio of latent heat of vapourization of water in soybeans to latent heat of vapourization of free water at various levels of moisture in beans

Source : Alam, A and Shove G.C. Hygroscopicity and thermal properties of soybeans. Trans. ASAE. 1973, 16 (4). pp : 707-9.

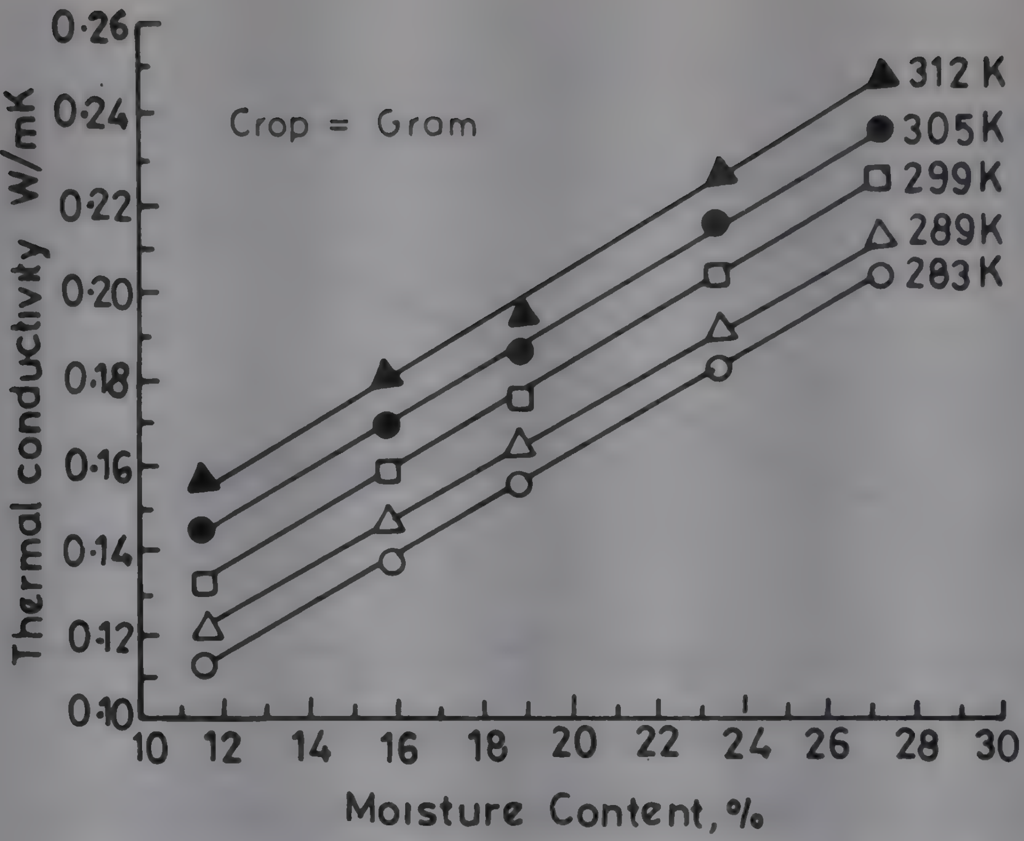


Fig. A16 : Variation of thermal conductivity with moisture content at different temperatures

Source : Dutta, S.K.; V.K. Nema and R.K. Bhardwaj. Thermal properties of gram. Jr. of Agril. Engng. Res. 1988, 39 (4), pp : 269-75.

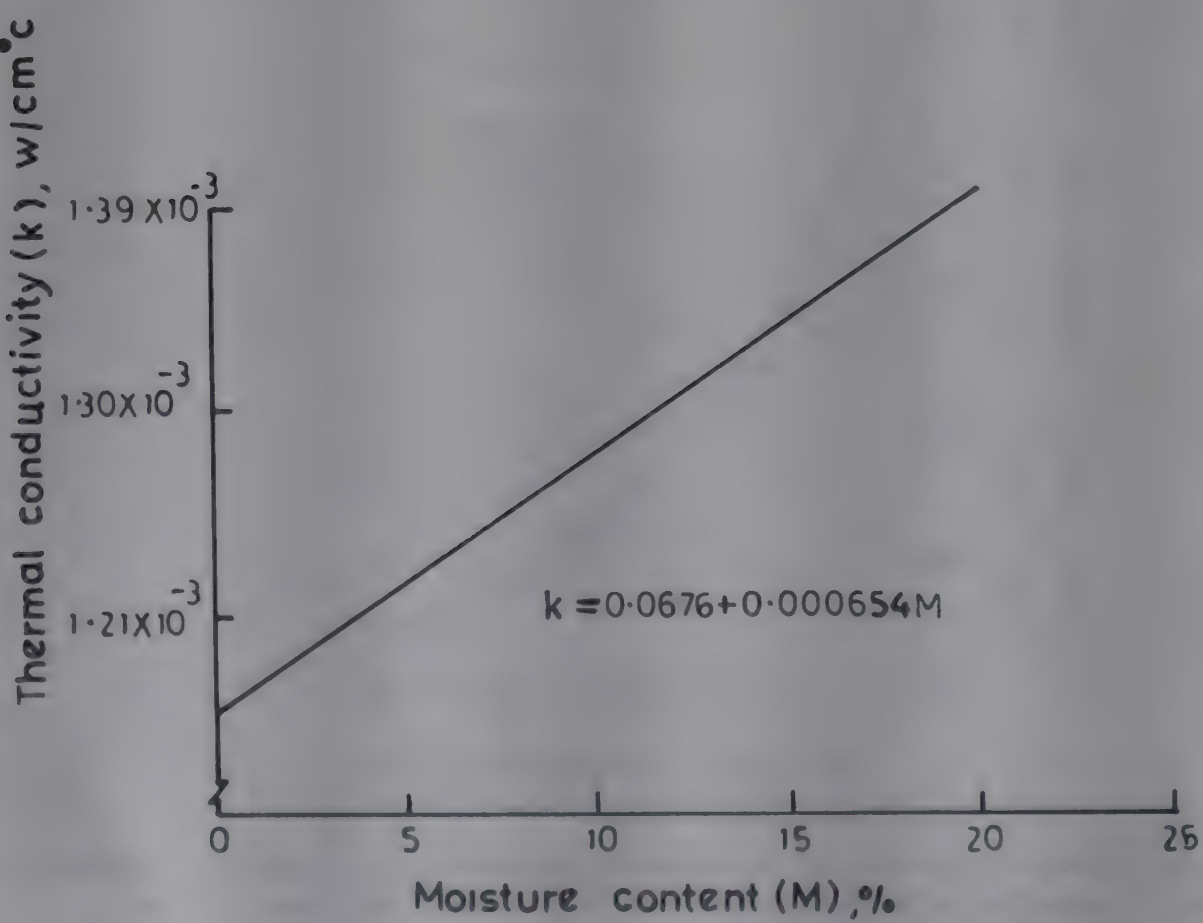


Fig. A17 : Relation between thermal conductivity and moisture content for white wheat

Source : Kazarian, E.A. and C.W. Hall. Thermal properties of grains. Trans. ASAE. 1965, 8(1). pp : 337-48.

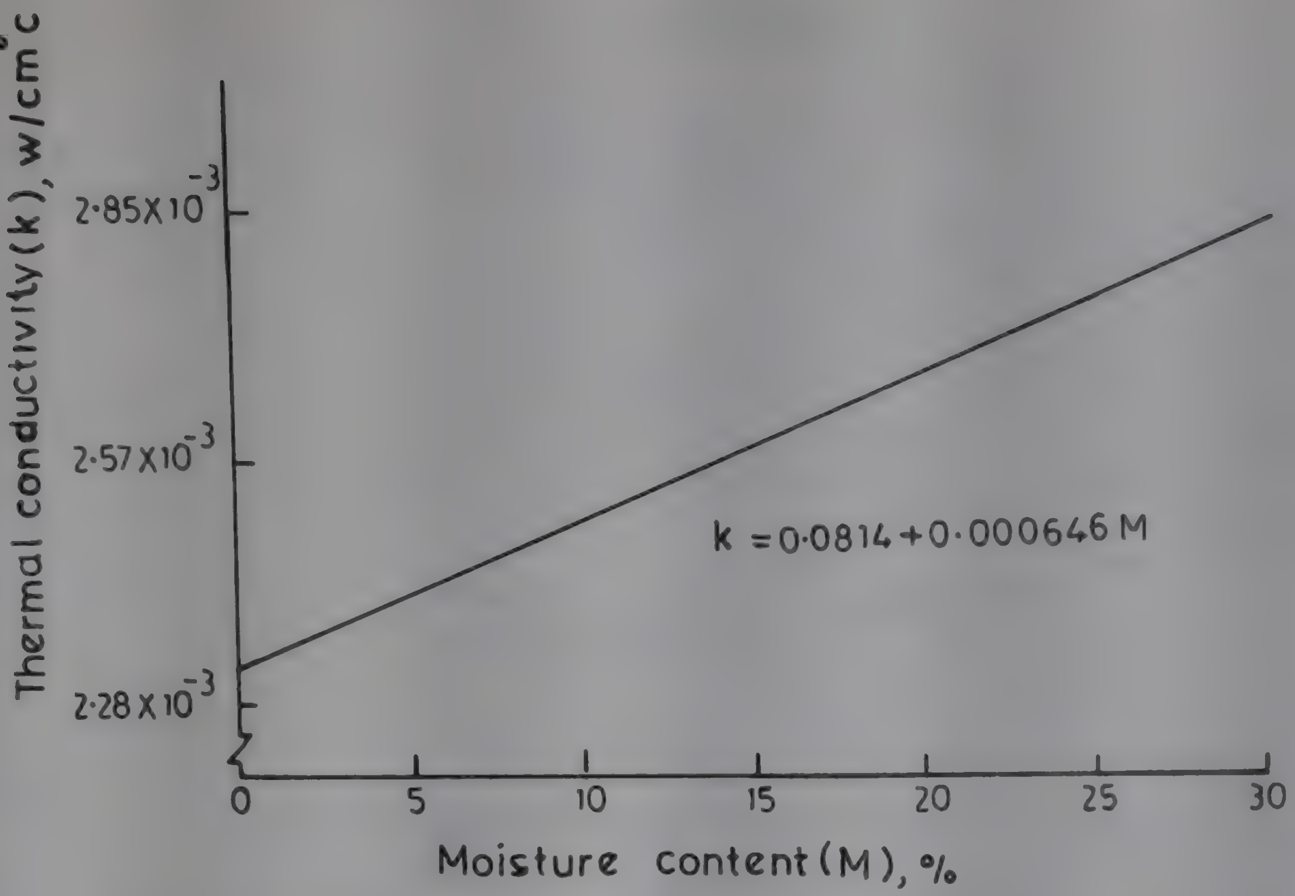


Fig. A18 : Relation between thermal conductivity and moisture content for corn

Source : Kazarian, E.A. and C.W. Hall. Thermal properties of grains. Trans. ASAE. 1965, 8(1). pp : 337-48.

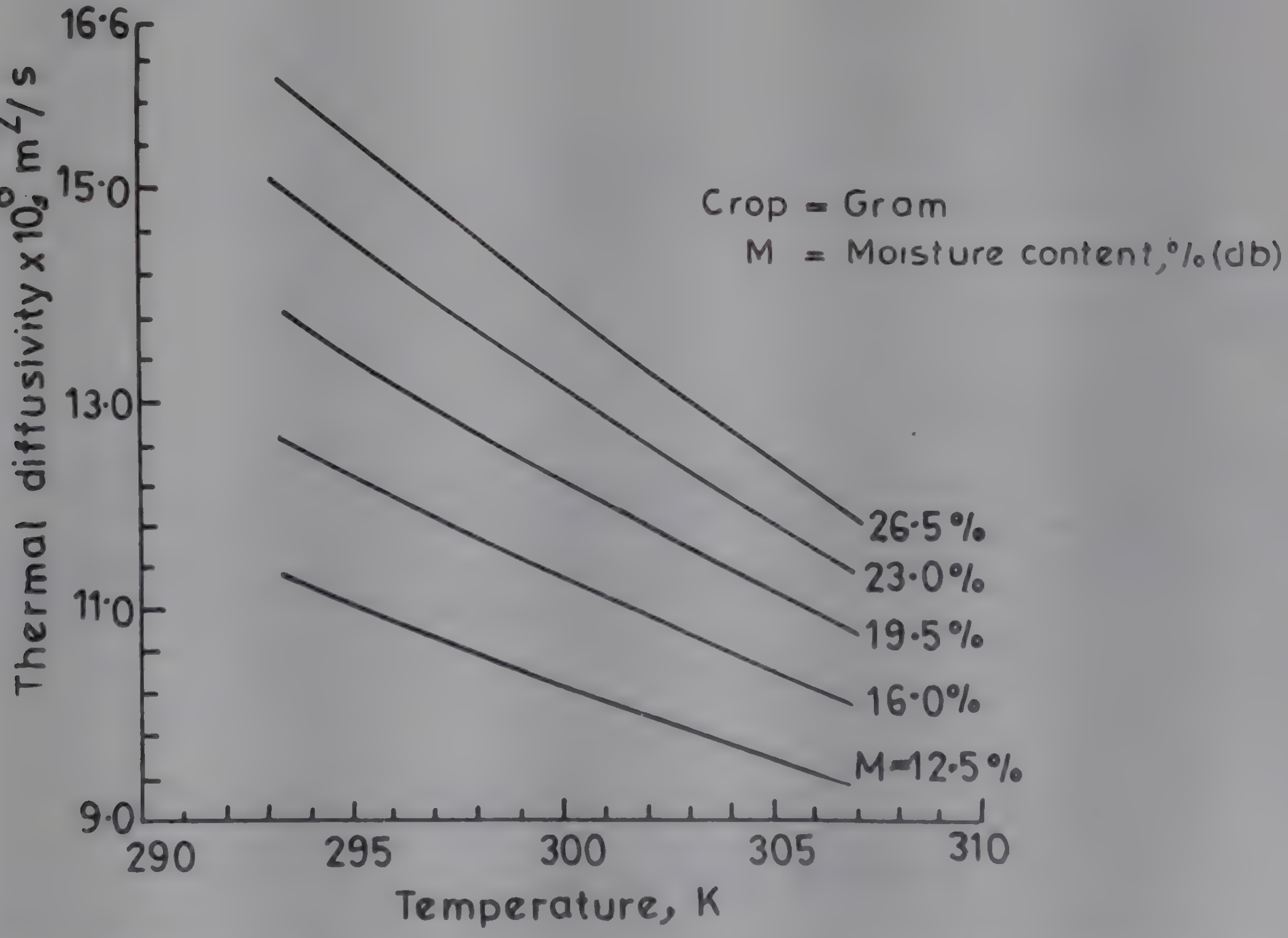


Fig. A19 : Thermal diffusivity as a function of temperature and moisture content

Source : Dutta, S.K.; V.K. Nema and R.K. Bhardwaj. Thermal properties of grains. Jr. of Agril. Engng. Res. 1988, 39 (4). pp : 269-75.

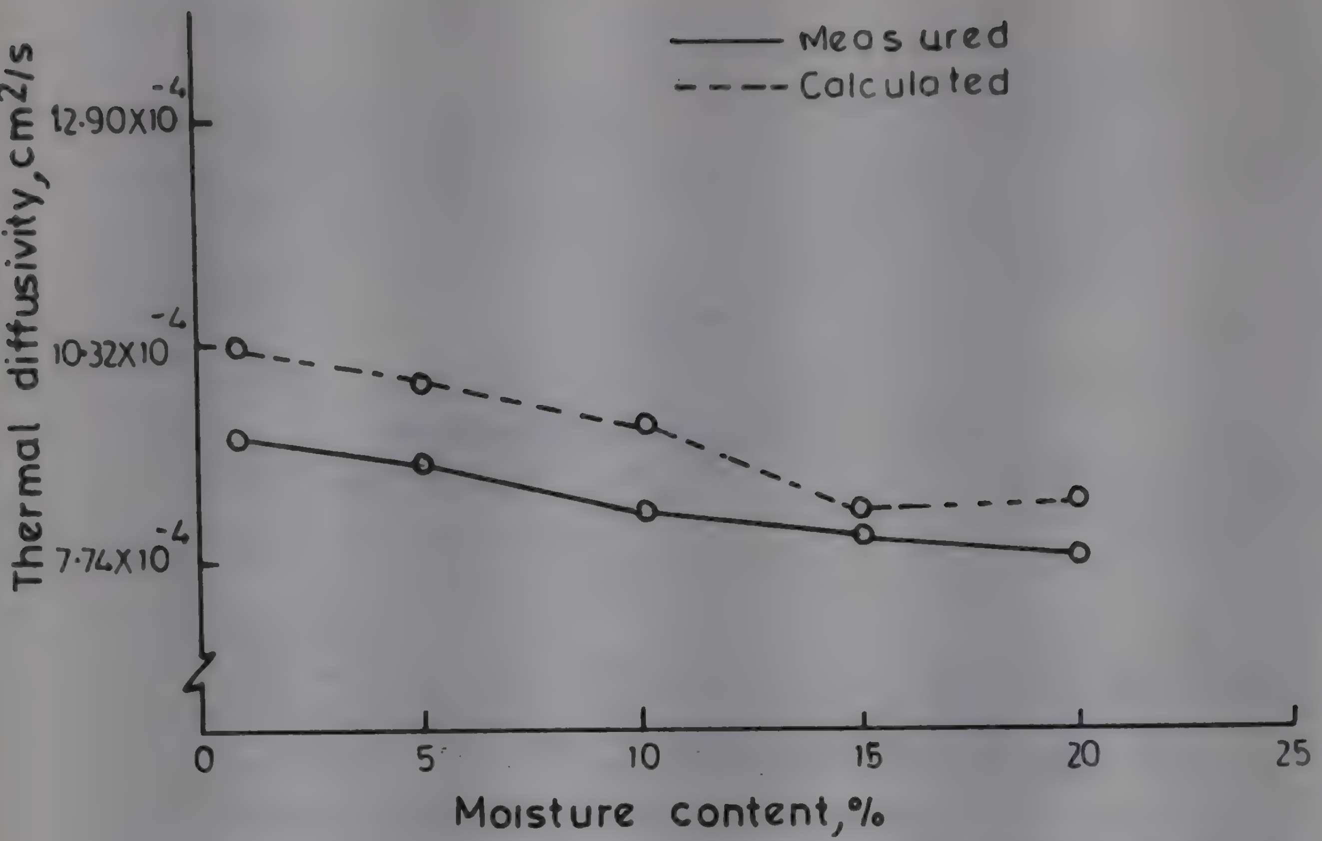


Fig. A20 : Relation between thermal diffusivity and moisture content for wheat

Source : Kazarian, E.A and C.W. Hall. Thermal properties of grains. Trans. ASAE. 1965, 8(1). pp : 337-48.

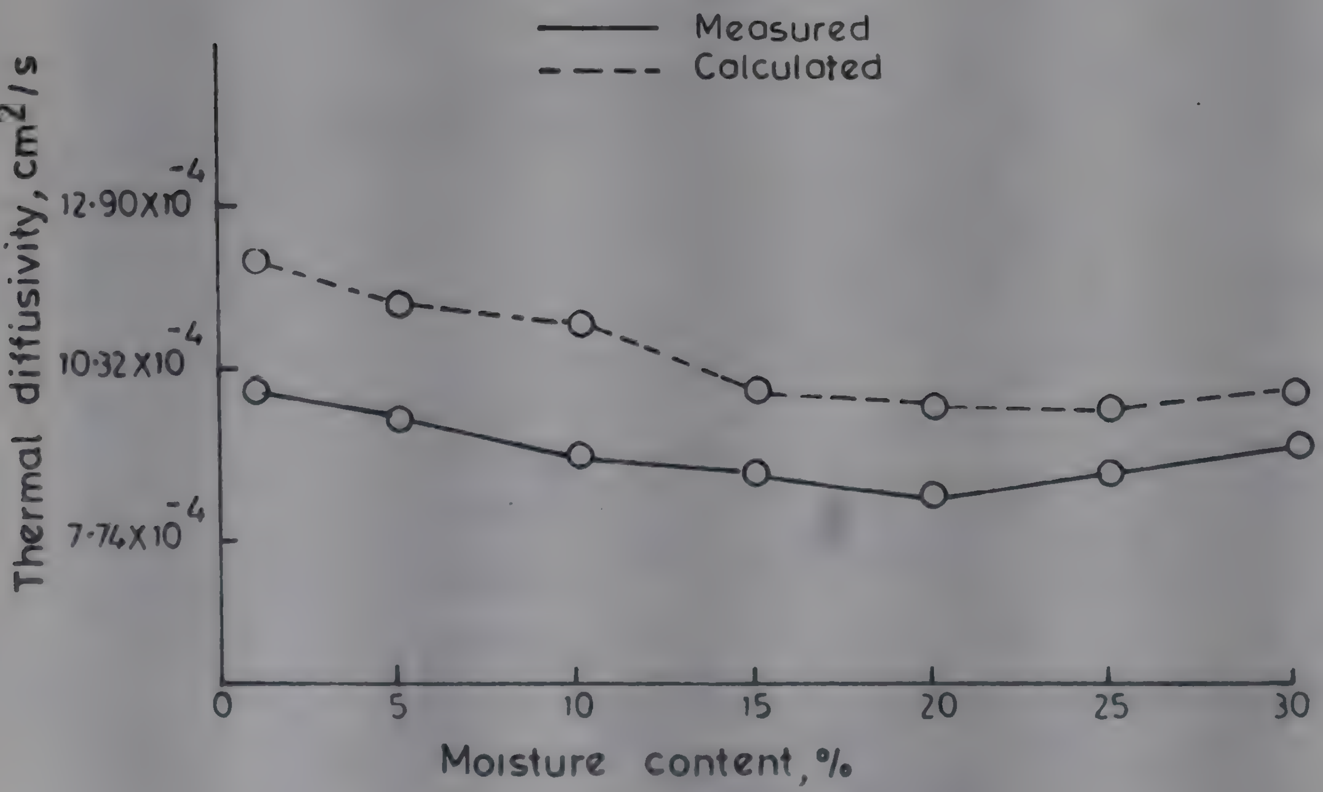


Fig. A21 : Relation between thermal diffusivity and moisture content for corn

Source : Kazarian, E.A. and C.W. Hall. Thermal properties of grains. Trans. ASAE. 1965, 8(1). pp : 337-48.

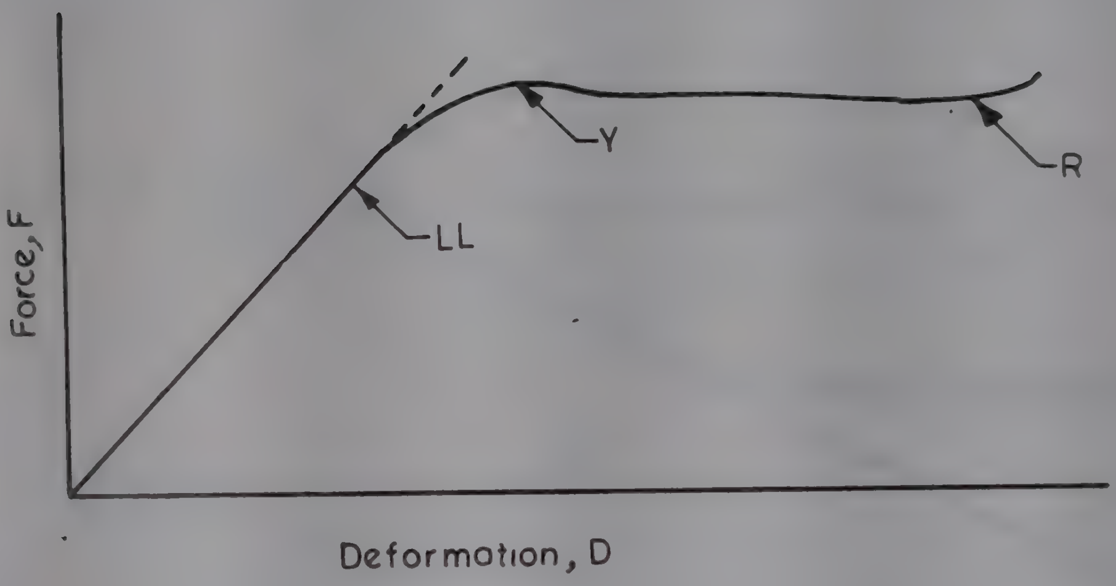


Fig. A22 : Possible force deformation curve for an agricultural product, LL : linear limit; Y : bioyield point and R : rupture point

Source : Nuri, N. Mohsenin. Physical properties of plant and animal materials. Gordon and Breach Science Publishers, New York, 1990.

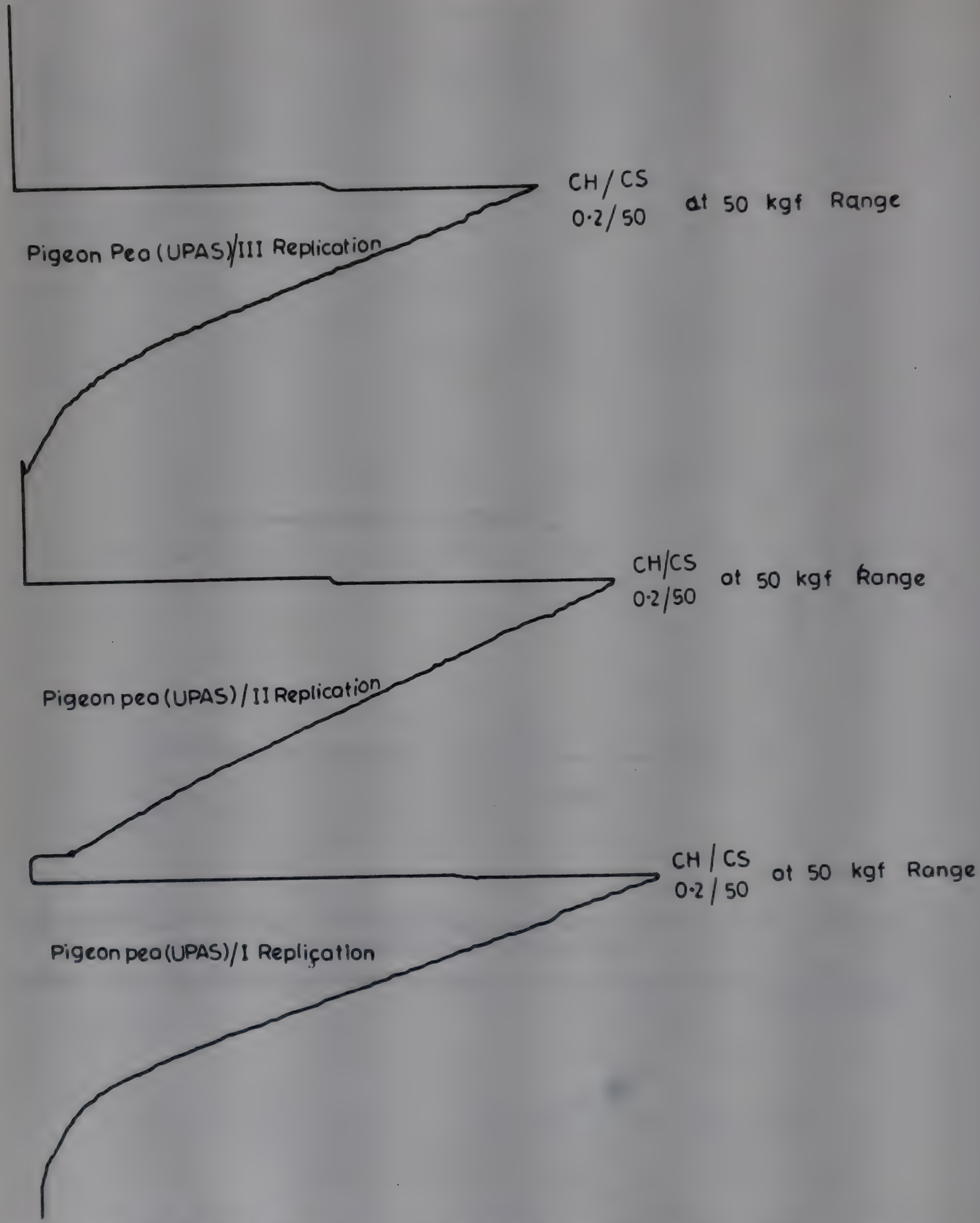


Fig. A23 : Force deformation curve for pigeon pea at moisture content of 12% (w.b.)

Source : Gupta, R.K. and Saurabh Prakash. Final Report (RPF- III). Physical, aerodynamic, rheological, thermal and biological properties of oilseeds and pulses. 1991, CIAE, Bhopal.

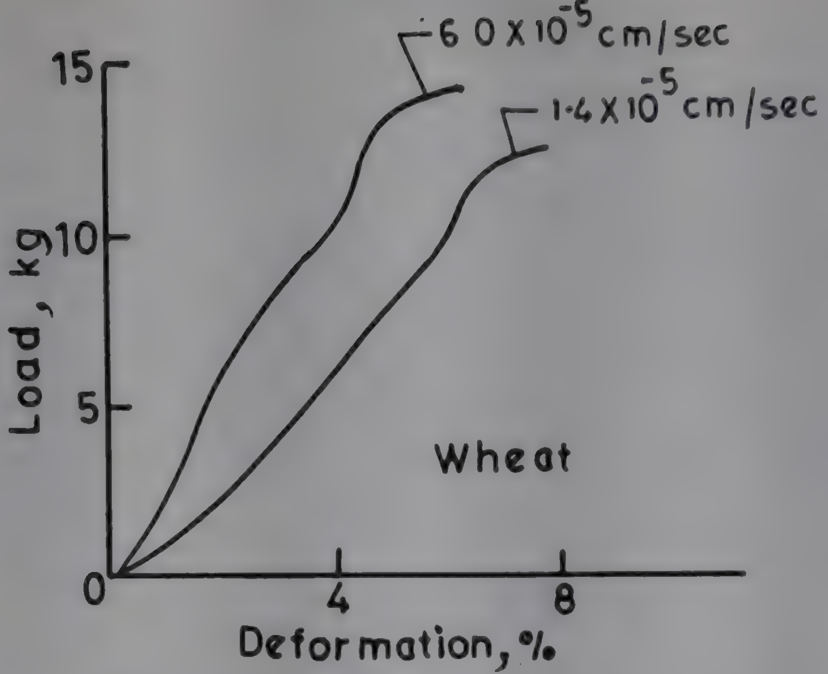


Fig. A24 : Force deformation curve for wheat

Source : Nuri, N. Mohsenin. Physical properties of food and agricultural materials. A teaching manual.Gordon and Breach Science Publishers. New York, 1981.

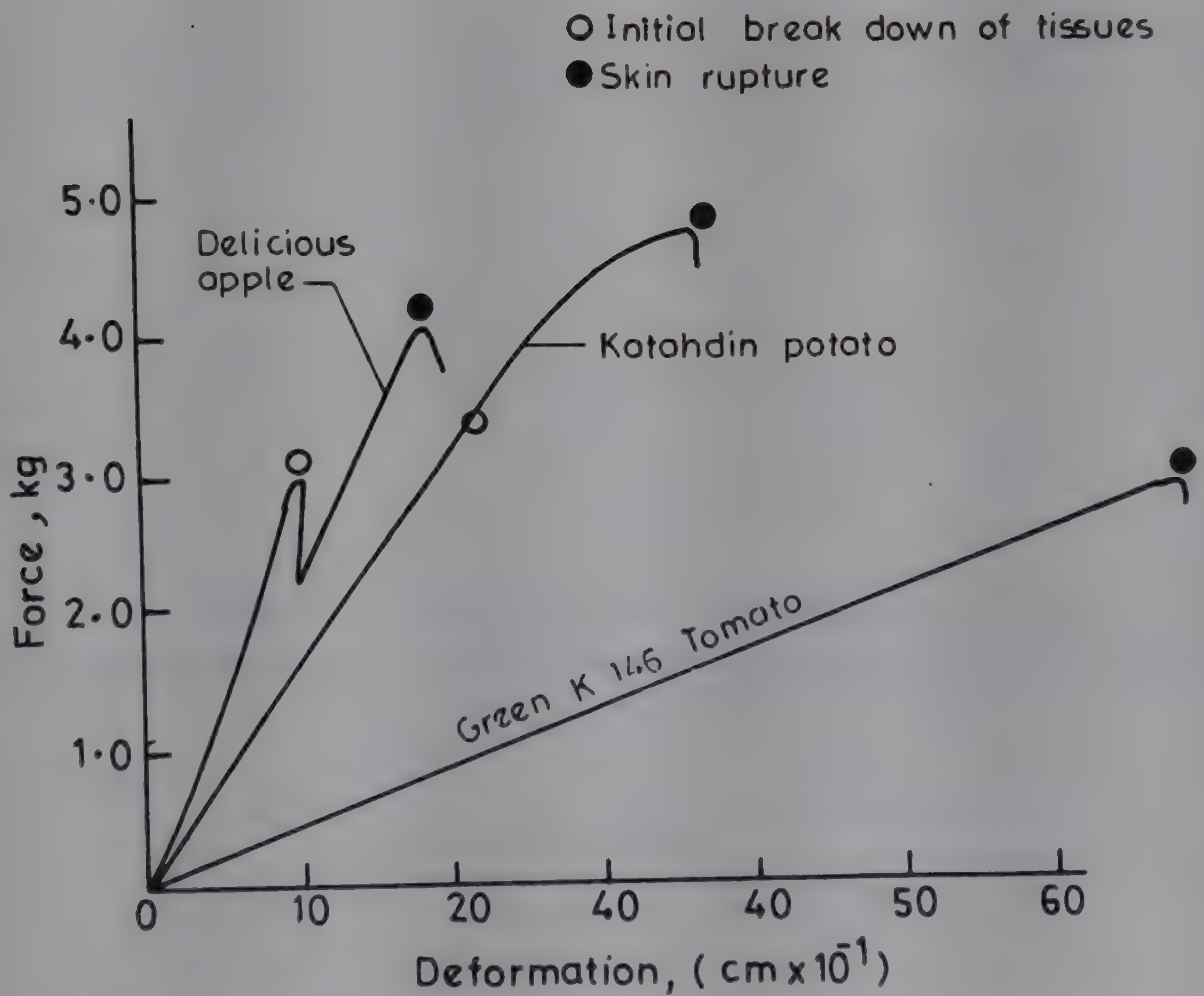


Fig. A25 : Force deformation curves for various perishable agricultural products

Source : Nuri, N. Mohesenin. Physical properties of food and agricultural materials. A teaching manual. Gordon and Breach Science Publishers. New York, 1981.

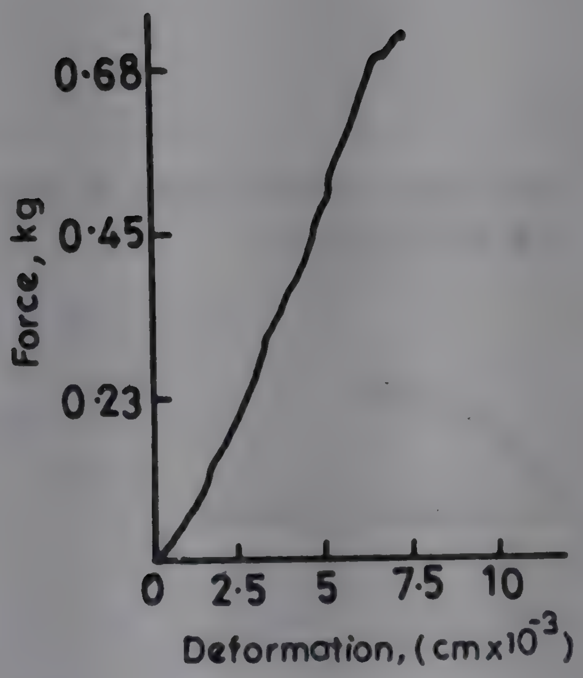


Fig. A26 : Load deformation curves for golden delicious apples

Source : Nuri. N. Mohsenin. Physical properties of food and agricultural materials. A teaching manual. Gordon and Breach Science Publishers. New York, 1981.

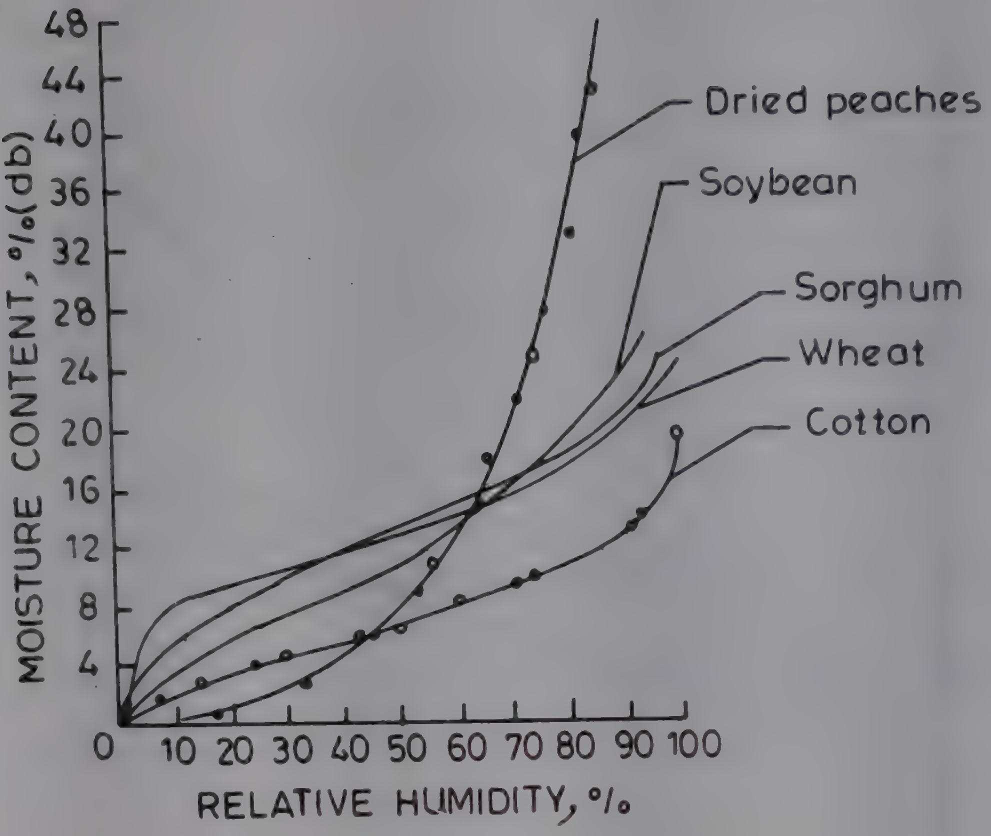


Fig. A27 : Equilibrium moisture curves for several agricultural products (Henderson-1952)

Source : Carl, W. Hall. Drying Farm Crops. Lyall book depot, Ludhiana, 1970.

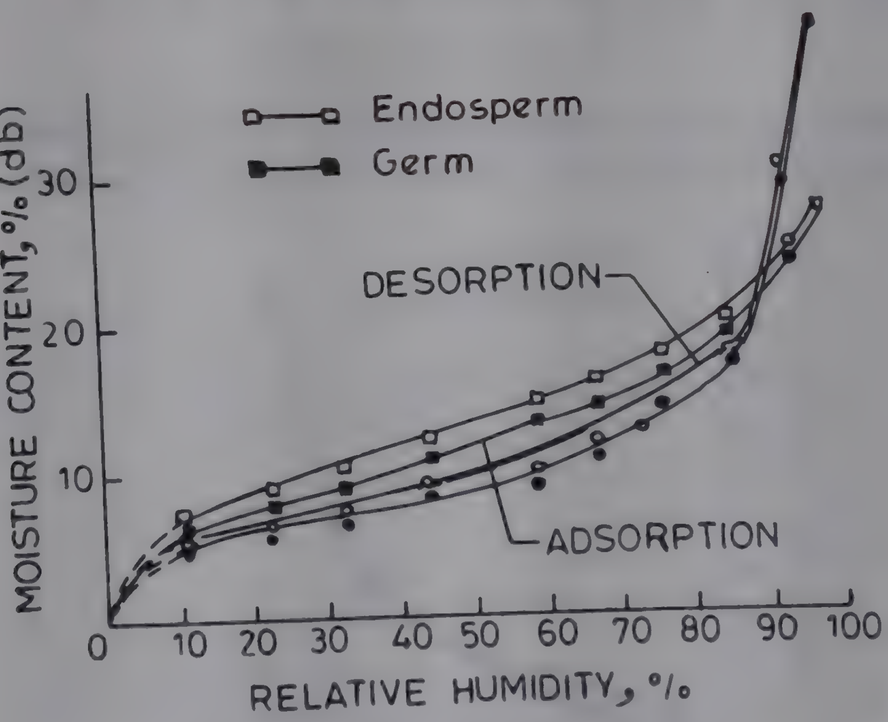


Fig. A28 : Sorption-desportion isotherms for germ and endosperm in corn kernel at 74°F (23.3°C) (Shelef and Mohsenin)

Source : Carl, W. Hall. Drying Farm Crops. Lyall book depot, Ludhiana, 1970.

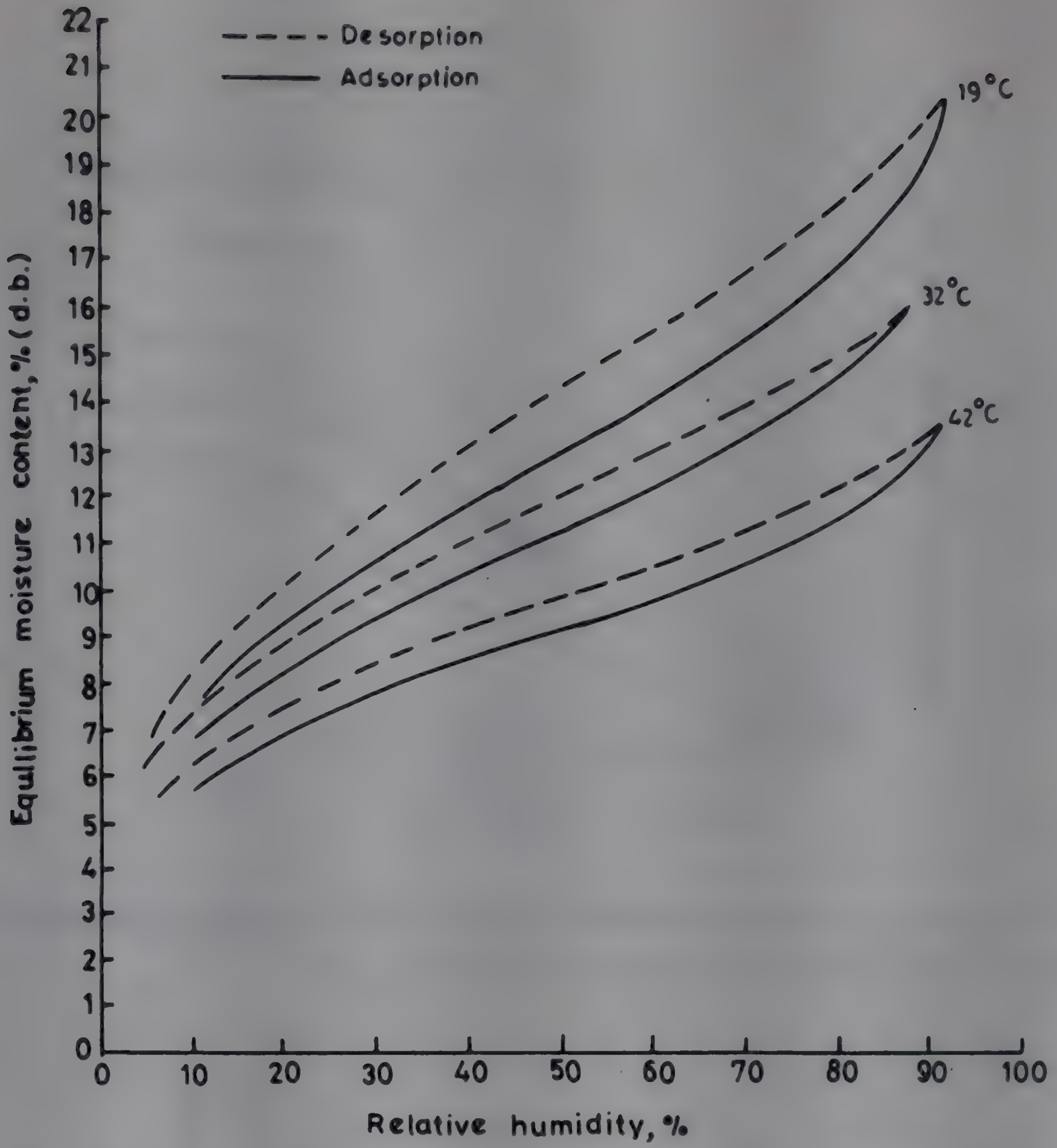


Fig. A29 : Variation in equilibruim moisture content with relative humidity

Source : Kachru, R.P. Scanning of hysteresis loop in sorption for rough rice. Jr. Agril. Engg. 1984, 21 (1&2), pp : 62-8.

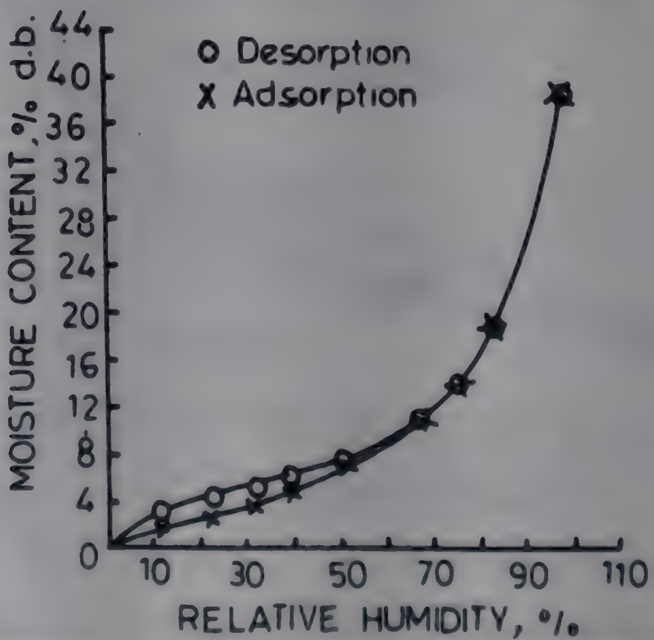


Fig. A30 : Hysteresis in adsorption and desorption of water in soybean at 45° C

Source : Alam, A and G.C. Shove, Hysteresis associated with hygroscopicity of soybeans. JAE, 12(1), 1975, pp : 6-9.

APPENDIX – III

Instrumentation required for determination of various properties of food crops

1. Spatial dimensions, size and sphericity

Shape	Shadow graph
	Charted standard for describing the shape of an object (given in the text)
Spatial dimensions	Travelling microscope (with cross aids and equipped with illuminating device)
	Micrometer

2. Gravimetric properties

Thousand grain weigh	Electronic balance
	Indian Standard; IS:4333 (Part IV) - 1968 may also be referred
Volume	Air comparison pycnometer
	General purpose reagent (toluene rectified) and measuring cylinder
Bulk density	Electronic balance
	Indian Standard; IS: 4333 (Part III)-1967 may also be referred
Specific gravity	Specific gravity balance
	Specific gravity gradient tube
	General purpose reagent (toluene rectified) and measuring cylinder
Surface area/ projection area	Overhead projector

3. Frictional properties

Angle of repose	Graduated scale
	Indian Standard; IS : 6663-1972 may also be referred
Co-efficient of externa internal friction	Set-up as explained in the text
	Measuring weights

4. Aerodynamic properties

Terminal velocity	Adjustable speed blower
	Hot wire anemometer
	'VANE' type electronic anemometer

5. Rheological properties

Deformation load compressive strength, crushing load etc.	Universal Testing Machine (INSTRON)

6. Thermal properties

Specific heat	Calorimeter
	Electronic balance
	Temperature recorder
	Indian Standard; IS: 10699-1983 may also be referred
Thermal conductivity	Rheostat
	Voltmeter
	Ammeter
	Battery
	Temperature recorder
	Thermocouples
	Set-up as explained in the text
Thermal diffusivity	Immersion heater
	Water bath
	Thermocouples
	Wattmeter
	Electric motor
	Temperature recorder
	Indian Standard; IS : 10698-1983 may also be referred

7. Hygroscopic properties

Equilibrium moisture content	Set-up having controlled temperature (hot-air oven)
	Temperature recorder
	Hygrometer
	Electronic balance (LC : 0.0001 g)
	Various saturated salt solutions to maintain a particular relative humidity as given in the text
	Humidity controlled oven with cooling arrangement

8. Chemical properties/constituents

Protein content	Micro-Kjeldahl apparatus
	Digestion chamber/heater
	Electronic balance (LC : 0.0001 g)
Fibre content	Muffle furnace
	Electronic balance (LC : 0.0001 g)
Carbohydrate content	Electronic balance (LC : 0.0001 g)
	Glass wares
Fat content	Soxlet apparatus
	Electronic balance (LC : 0.0001 g)
FFA content	Flask shaker
	Electronic balance (LC : 0.0001 g)

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